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STUDENT REPORT

A COMPUTER ENGINEERING CURRICULUM FOR THE AIR FORCE ACADEMY: AN IMPLEMENTATION PLA

Major Legand L. Burge, Jr., USAF 85-0335

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REPORT NUMBER 85-0335

TITLE A COMPUTER ENGINEERING CURRICULUM FOR THE AIR FORCE ACADEMY: AN IMPLEMENTATION PLAN

AUTHOR(S) MAJOR LEGAND L. BURGE, JR., USAF

FACULTY ADVISOR MAJOR CHARLES ZIMMER, ACSC/EDCM

SPONSOR COLONEL ERLIND G. ROYER, HQ USAFA/DFEE

Submitted to the faculty in partial fulfillment of requirements for graduation.

AIR COMMAND AND STAFF COLLEGE
AIR UNIVERSITY
MAXWELL AFB, AL 36112

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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS N/A
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) 85-0335	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION ACSC/EDCC 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code) Maxwell AFB, AL 36112	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State and ZIP Code)	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT NO.
11. TITLE (Include Security Classification) A Computer Engineering Curriculum for the Air Force Academy:	
12. PERSONAL AUTHOR(S) Burge, Legand L. Jr., Major, USAF	
13a. TYPE OF REPORT 13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Yr., Mo., Day) 1985 April 15. PAGE COUNT
16. SUPPLEMENTARY NOTATION An Implementation Plan	
17. COSATI CODES FIELD / GROUP / SUB. GR.	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The recent advances in computer technology which impact present and future Air Force systems led the Air Force Academy to include computers and information systems engineering courses in the curriculum. This analysis addresses the issue of a major in computer engineering at the Academy. The Air Force computer engineer (AFSCs 2625, 2736 and 2885) specializes in designing, developing, installing, and testing embedded computer systems in aircraft, missiles,flight simulators, and command, control, and communications systems. An embedded computer system is all computer equipment, programs, data, documentation, personnel, and supplies integral to a defense system from the design, acquisition, or operations and support point of view. This report addresses the Air Force need for computer engineers, the need for the computer engineering major at the Academy, the appropriate department to administer the major, the structure of the degree, and the implementation of the discipline at the Academy.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL ACSC/EDCC Maxwell AFB, AL 36112	22b. TELEPHONE NUMBER (Include Area Code) (205) 293-2483 22c. OFFICE SYMBOL

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

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PREFACE

The invention of the microprocessor in the early 1970's opened the door to an almost unlimited variety of computer applications. For the Air Force, this meant smarter weapons and weapon-support systems, more accurate navigation devices, and faster, more reliable command, control, and communications systems. As computer applications expand, so does the need for engineers educated in the theory and practice of computer system hardware, software, and design. This new emerging engineering field combining the hardware and software of a computer system into a more global industrial, defense, and consumer system has become known as computer engineering. In the Air Force, computer engineering is the engineering and management of embedded computer resources into Air Force weapon and weapon-support systems. The Air Force-wide requirement for officers with an educational background in the computer engineering area was established on 30 April 1984. The Air Force Academy Department of Electrical Engineering has considered the requirement for the Academy input.

In this paper, it is recommended the Air Force Academy adopt computer engineering as a major discipline of study. This report documents the study effort and recommends an implementation for the major in the Department of Electrical Engineering.

In this report, citations represented by "(XX:--)" are used for document and interview references.

The author acknowledges with sincere thanks Major Charles Zimmer, my advisor, for advice and use of the computer facilities. The Air Force Academy faculty and personnel are acknowledged for assistance with collecting documents. The author expresses a wealth of gratitude to Colonel Erlind G. Royer, Permanent Professor and Head of the Department of Electrical Engineering at USAFA and the DFEE faculty and personnel for assisting with administration and data collection.

I owe special thanks to Glenn and Carolyn Johnson for their inspiration throughout this work.

CONTINUED

The cooperation, patience and understanding of my wife, Claudette, has been greatly appreciated. My son and daughters, Legand, LeAnn, and Lamuelle, are acknowledged for their continued source of motivation for this effort.

ABOUT THE AUTHOR

Major Legand L. Burge, Jr. [redacted]. He earned his commission in 1972 through the Air Force ROTC program at Oklahoma State University, where he received the Bachelor of Science, Masters of Science, and Doctoral degrees in Electrical Engineering. Major Burge's career began in space systems. He served as a flight engineer, satellite operations engineer, and plans and analysis officer at the Satellite Test Center, Sunnyvale, California under the Secretary of the Air Force, Special Projects, SAMSO at Sunnyvale Air Force Station, California. During his tour in California, he worked the operations of on-orbit satellite systems and the planning of satellite missions. Next, in Oklahoma his duty position was a research associate investigating voice processing systems with AFIT at Stillwater, Oklahoma. He continued researching efforts in speech synthesis, voice recognition and information processing systems with his tour at the Air Force Academy. During the recent years, he has published several papers and is one of the Air Force authorities on speech processing. While at the Air Force Academy, he served as an Associate Professor of Electrical Engineering.

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EXECUTIVE SUMMARY

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REPORT NUMBER 85-0335

AUTHOR(S) Major Legand L. Burge Jr., USAF

TITLE A COMPUTER ENGINEERING CURRICULUM FOR THE AIR FORCE ACADEMY: AN IMPLEMENTATION PLAN

I. PURPOSE: To determine and design an accredited computer engineering curriculum for the Air Force Academy.

II. PROBLEM: Due to recent advances in computer technology, sufficient evidence existed to justify establishing new computer specialities in the Scientific and Development Engineering (S&DE) career fields. Since the Academy inputs officers into the Air Force mainstream, questions were raised concering the United States Air Force Academy (USAFA) curriculum. This perspective required an examination of the USAFA need for the computer engineering discipline, requirements for the curriculum, and to answer questions concerning implementation and accreditation.

III. DATA: The invention of the microprocessor in the early 1970's opened the door to an almost unlimited variety of computer applications. For the Air Force, this meant smarter weapons and weapon-support systems, more accurate navigation devices, and faster, more reliable command, control, and communications systems as examples. As computer applications expand, an increase in engineers educated in the theory and practice of computer system hardware, software, and design is needed. The new emerging engineering field combining the hardware and

software of a computer system into a more global industrial, defense, and consumer system has become known as computer engineering. In the Air Force, computer engineering is the engineering and management of embedded computer resources into Air Force weapon and weapon-support systems. The Air Force-wide requirement for officers with an educational background in the computer engineering discipline was established on 30 April 1984. This has prompted USAFA Department of Electrical Engineering to consider the requirement. The department has been actively teaching and later examining the viability of the discipline of computers and engineering as a major curriculum since 1974. This discipline will allow a substantial knowledge base for future Air Force officers, an expertise the Air Force needs, and an accessibility of qualified personnel to fill an emerging technological field with an engineering perspective in management.

IV. CONCLUSIONS: This report investigated the computer engineering discipline as a viable major for USAFA. Due to the Air Force need, the Academy mission of preparing leaders, the current technological background needed for Air Force programs, and the Academy input to the Air Force mainstream the discipline should be taught at USAFA.

V. RECOMMENDATION: The Dean of Faculty approve the Computer Engineering discipline as a major curriculum. After formal incorporation, the discipline should be offered as an option in the Electrical Engineering major to the Class of 1987. The Department of Electrical Engineering should seek accreditation after the graduation of the Class of 1987.

CHAPTER ONE

BACKGROUND AND ISSUES

INTRODUCTION

Recent advances in computer technology have caused the United States Air Force Academy (USAFA) to include computers and systems engineering courses in the Academy curriculum. In many colleges, these courses have led to the development of an academic major called computer engineering. To this end, the purpose of this paper is to discuss this development at USAFA. First, the report describes the Air Force need for computer engineers. Then, there is a discussion on the design of a curriculum which will support the USAFA mission and meet the criteria of the Accreditation Board for Engineering and Technology (ABET). Lastly, the paper examines an implementation plan for the discipline leading to a Bachelor of Science in Computer Engineering at the United States Air Force Academy.

The following definitions used in this paper are given for reference. The reader should understand that the Air Force Computer Engineer specializes in designing, developing, installing, and testing embedded computer systems (ECS) in aircraft, spacecraft, missiles, flight simulators, and communication systems (64:1,69:2). An ECS is all computer equipment, programs, data, documentation, personnel, and supplies integral to a defense system from the design, acquisition, or operations and support point of view (24:9).

BACKGROUND

As a result of a USAFA study on the "Role of Electronic Computers in the Electrical Engineering Department" during 1973-1974, microcomputers were introduced in that department with the following conclusions (14:158;15:--;16:--):

1. Microcomputers represent a quantum jump in technology.
2. The non-electrical engineering major should be introduced to the basic operations of microcomputers,

since the officer will encounter an increasing number of microcomputers in his/her Air Force career.

3. The electrical engineering major should be taught the operation and system design of microcomputer systems so that the officer can specify microprocessor systems for the Air Force.

That study was the impetus for courses focused on hardware and software issues for single chip microcomputers. The department developed a set of courses which were called the digital systems track, or affectionately referred to as the "computer track," building on the initial core course, Digital Signals and Systems (EE 210), which is taken by all cadets regardless of their majors (15:6-10).

The initial course in the sequence develops the philosophy for Department of Electrical Engineering instruction. Since the course is one of two which the non-electrical engineering cadet takes, it presents a perceptual challenge. Cadets take this course because a future Air Force officer needs a perspective of the impact of technology. Also, a cadet should be able to solve technical problems as an Air Force officer.

In 1979, Brigadier General Roland E. Thomas, USAF (Retired), promoted a philosophy which is the thread through which the computer track and the electrical engineering curriculum is developed (31:99). He concluded the core course should

1. Provide an understanding of the application of the engineering method to electronic systems.
2. Acquaint the cadet with the viewpoint and terminology of electrical engineering,
3. Provide some perspective on the impact of electronics on weapons technology, and
4. Prepare the cadet for a world of accelerating technological change and thus prepare the cadet for a world in which education must be a continuing process(31:99).

In 1979, when these tenets were presented, it was the era of the fourth generation computer. Now the age of the fifth generation computer or the superprocessor is developing (29:4;30:68;32:34). The impact of the superprocessor is felt by today's cadet as he prepares to be an Air Force officer. The trend now is for an officer to be exposed to parallel and multiprocessor architecture; machine organization which can execute large-scale engineering and scientific algorithms; and the design, interface, and programming of supercomputers for the aerospace systems of today (29:4). It was the insight of General Thomas which laid the ground work for a study of computer engineering that will be discussed next.

COMPUTER ENGINEERING TASK FORCE AND ISSUES

The Department of Electrical Engineering formed a Computer Engineering Task Force (CETF) to study the viability of implementing a computer engineering curriculum at the United States Air Force Academy in 1983 (69:1-2). The following objectives of the study were:

1. Determine job characteristics of an Air Force computer engineer.
2. Develop a course structure for a computer engineering curriculum.
3. Develop course content for courses.
4. Determine manpower required to support the curriculum.
5. Develop a schedule for implementing a computer engineering curriculum(69:1-2).

The following CETF issues are addressed in this report (69:9,4-8):

1. What is the impact on the Computer Science Department courses required by the computer engineering major?
2. What is the impact on the Electrical Engineering Department shifting and/or increasing enrollment?
3. What is the impact on the Mathematical Sciences Department in developing a course?
4. Should the computer engineering program be an expanded track in the Electrical Engineering degree or a separate academic degree?
5. What is the impact of the Accreditation Board for Engineering and Technology (ABET) accreditation of the Electrical Engineering degree? Should the Electrical Engineering Department seek accreditation of the computer engineering option? If so, when?
6. What graduate school options exist for graduates with a Bachelor of Science in Computer Engineering? Are any scholarships currently available?
7. Will all laboratory courses in the computer engineering curriculum be embedded within the courses or a separate course?
8. What is the meaning of the Institute of Electrical and Electronics Engineers, Inc. (IEEE) and ABET criteria IV.C.1.c.(2) and (3) which state "... and basic modeling techniques used to represent the computing process" ?
9. What other implementation questions related to curriculum change proposals and new course justification should be considered? (69:9,4-8)

Much of the CETF effort dealt with data collection, course reviews, and analysis and surveys from major Air Force commands. However, the CETF was also instrumental in writing the description of the Officer Air Force specialty for all computer

engineering officers found in AFR 36-1 (65:--). These officer specialty codes are discussed in Chapter Two. Also discussed in Chapter Two are USAFA parameters and current technology trends. In Chapter Three, a discussion is given about the computer engineering option as a discipline in the curriculum of the Academy. In Chapter Four, the computer engineering degree is described for the Air Force Academy academic program. The structure of the developed curriculum is compared to the model computer engineering program of the IEEE Computer Society. Included in this chapter is a discussion of the accreditation process, and the criteria for accreditation in computer science and engineering are presented. Finally, in Chapter Five, an implementation plan is discussed.

CHAPTER TWO

AIR FORCE SPECIALTY CODES AND CURRENT COMPUTER TECHNOLOGY TRENDS

AFR 36-1, dated 30 April 1984, identifies specialty codes for computer engineers: the computer research scientist (2625), the computer systems acquisition manager (2736), and the computer systems engineer (2885) (62:A10). The author discusses briefly each Air Force Specialty below. A complete description appears in Appendix A. Also discussed are parameters the Air Force Academy considers for a viable discipline, the trend of current computer technology and education, and future Air Force needs.

SUMMARY OF AIR FORCE SPECIALTY CODES

The computer research scientist (2625) "conducts and manages computer technology research, develops new concepts, methods, and techniques..."(62:A10). The computer systems acquisition manager (2736) "formulates, plans, and organizes computer technology research, manages systems research and development activities, and provides acquisition program support" (62:A10). The computer systems engineer (2885) "designs, develops, coordinates computer technology research programs, and plans and organizes computer research and development engineering programs" (62:A10).

Each officer specialty requires an undergraduate specialization in computer engineering or electrical engineering or electronics engineering (with emphasis in computer engineering or computer science) in a school with a program accredited by an accrediting body such as ABET or a master's degree in computer engineering, computer science, or mathematics. For the computer research scientist and computer systems engineer, the grade spread begins at second lieutenant. In the next section, the parameters for a viable discipline at the Air Force Academy are presented.

PARAMETERS FOR CONSIDERATION

The parameters for a viable discipline at the Air Force Academy are cadet interest, Air Force needs, and expected acquisitions.

Each of these parameters will be discussed in the following paragraphs.

An academic major at USAFA can only exist if cadet interest keeps the major viable. In the past five years, several reasons have caused a significant number of cadets to enroll in the electrical engineering computer track (69:1). First, the push for computer use in the Fourth Class (freshman) year implants desire to learn about computers in a required course entitled Introduction to Computer Science (CS 100). Second, cadets in their sophomore year complete EE 210, the first electrical engineering core course. Finally, cadets use of computer-aided instruction in other courses which merely adds to their original experience in CS 100 or EE 210. As a result, these courses generate interest in computers and electrical engineering (54:C-15;C-19;58:65).

Secondly, a major at USAFA must fulfill a need in the Air Force. According to Captain Nancy Strasser, Manager, Research and Development Resources, at the Air Force Military Personnel Center (AFMPC), the Air Force has requirements for the various computer engineer specialties (72:--). Captain Strasser said those cadets who graduate in the electrical engineering discipline and computer engineering can find jobs in Air Force Systems Command (AFSC), Air Force Communications Command (AFCC), and Air Force Logistics Command (AFLC) (72:--). Lieutenant General Lawrence A. Skantze, DCS/Research, Development, and Acquisition, Headquarters Air Force, recently provided data which forecasts the computer resources manpower in the scientific and development engineering career area (68:--;70:--). Table 1 below summarizes General Skantze's data for each of the new Air Force specialty codes (68:Table 1).

	LT	CAPT	MAJ	LT COL	COL
26XX	60	52	12	-	-
27XX	-	-	100	21	10
28XX	210	310	4	-	-

TABLE 1. Computer Resources Manpower Forecast For FY85

The table represents the expected acquisitions for FY85 when each of the new specialties is implemented (67:--). These numbers, however, only show HQ AFSC and HQ AFLC inputs. The other

commands have identified 19 positions which were not given a specialty code or rank. General Skantze emphasizes these are immediate Air Force needs. HQ AFSC expects future manpower requirements to increase to 150 for 26XX, 225 for 27XX, and 375 for 28XX. In summary, the data implies that the USAFA product is useful to the Air Force.

Further, Air Force officers with certain specialties can cross train with appropriate education and/or experience. Presently, AFMPC is examining the Research and Development resource (28XX), the Communication Electronics resource (30XX), and the Computer and Data Processing resource(51XX) for personnel who might qualify for the computer engineering specialties (72:--). According to General Skantze, there are other "potential sources for reclassification into the new Air Force specialty codes" (68:--). These specialties include 1835, 2635, 2716, 2724, 2816, 2825, 2835, 2845, 2855, 2895, 5116, 5135, 5176, 6524, 6534, 6924, and 8016 (68:--).

Lieutenant Colonel Charles Mote, Director of Computer Resources, Headquarters Air Force, estimates 1500 manpower requirements in all specialty codes for AFSC during FY85 (71:--). These personnel would have duty responsibility in Product Divisions and Test Wings of AFSC. However, Lieutenant Colonel Mote suggests that the new information systems Air Force Specialty Code, 49XX, clouds the computer engineering issue for personnel entering this Air Force Specialty Code since 49XX is to be composed of 30XX and 51XX personnel (71:--). This is an issue which must be monitored since some electrical engineering majors are selected for these career fields; however, it will not be addressed in this analysis.

Summarizing, this section discussed three computer engineering Air Force Specialties: the computer research scientist, the computer system acquisition manager, and the computer system engineer, codes 2625, 2736, and 2885, respectively. Also discussed are the parameters for USAFA: cadet interest for the computer engineering option and Air Force jobs. Since an immediate need for the computer engineering specialty exists, AFMPC is actively pursuing reclassifying several specialties. In the next section, the current computer technology trends are discussed.

The growth of technology is the main reason for the high interest at AFMPC for knowledgeable Air Force personnel. It is imperative future Air Force officers have the knowledge and exposure to high technology to develop managerial skills which fit Air Force needs. The remaining sections of the chapter discuss current computer technology trends and needs, current education trends, and future Air Force need. In this section, computer technology, computer software, and microelectronics are discussed.

CURRENT COMPUTER TECHNOLOGY TRENDS

The current computer technology trend is to continue to develop new generation microcomputer chips which compute faster, are smaller, and are less expensive for weapons systems. For example, the performance for up-and-coming fifth generation computers will be calculated in possibly gigainstructions per second (GIPS) to tetrainstructions per second (TIPS) (22:36). The technologies which allow for small sizes in hardware are the solid-state three-dimensional circuit designs using Josephson junction and Gallium arsenide, recently discovered chemical elements for electrical circuits, and optical components. As a result, there is less computer hardware cost. By recognizing computer hardware trends for faster, smaller, and less expensive computing power, Air Force people will be better able to understand and apply these technologies to aerospace and weapon systems.

The current trend in computer software is toward language systems such as ADA and expert systems which are object-oriented artificial intelligence languages. Artificial intelligence systems will be built around natural languages, vision, and speech recognition (10:406). As an example, some future machines will be able to "reason." Although reasoning is not possible with present-day computers, "they will begin to play a role in sensory processing and information management which gets closer to the central core of intelligent activity" (22:37). As a result, artificial intelligence software trends will play a dynamic part in future computer technology (22:37).

A final trend in computer technology is in the area of microelectronics used in embedded computer systems (ECS). The microelectronics produce fast and very small devices made of ultralarge scale chips. To develop a complete ECS, computer microelectronics systems and architectures will have to be developed into a working environment. The working environment may be one system or a large combination of many systems interworking together as in an ECS. The ECS interrelates hardware, software and any other tools which interface with the environment for development. As a computer engineer, merging all three areas requires special expertise in hardware, software, and systems design to create an interworking ECS (4:00;18:27-31;22:37). The trends in computer technology have a direct impact on education.

CURRENT EDUCATION TRENDS

Current computer technology continues to have a major impact on education in the United States (33:25). To offer up-to-date education, academic institutions must continually revise their curriculum. The institution must decide to do innovative things. For example, many colleges and universities now require students to purchase a personal computer. An institution must be willing to consider new ideas because of susceptibility to change, obsolescence of curricula, and demand of emerging programs.

The curriculum of an engineering school has always been susceptible to constant changes in technology. It is not unusual that state-of-the-art techniques, profound concepts, and sophisticated applications can become simple and well-known facts almost overnight. Therefore, an engineering school's curriculum should reflect current developments in the field (19:5).

A flexible and developing curriculum ensures students avoid an obsolete engineering education. An engineering faculty current in state-of-the-art developments, can pass these advancements to the student through lectures and laboratories. In addition, students with a current education are more likely to be properly prepared to enter a particular engineering profession than those enrolled in a dated curriculum. In the computer engineering profession, the student also should be familiar with the hardware, software, and systems environment in computer technology. This ensures that the student has all the expertise to merge the three areas in the profession.

Since technological changes impact education, it becomes a major effort to keep up-to-date programs. "The demand for educational programs in computer science and engineering has exceeded the ability of higher education to provide quality programs. As a result, a number of institutions have marginal or submarginal programs" (19:5). To try to remedy this situation and serve the student, education, and industry, the role of the Institute of Electrical and Electronics Engineers has been to award professional status and accreditation to programs that meet rigid criteria. To date, there are 31 engineering-based programs in the computer area which have been granted ABET accreditation (2:4;3:96;16:--;7:1-12). These schools appear in Appendix B. The references list other schools which have non-accredited computer engineering programs (34-53:--;64:--).

To maintain and develop an accredited program in engineering requires a major effort. The engineering curriculum must keep pace with advancing technology so students graduate with a sound background in engineering. As a result, the student gets up-to-date concepts and applications, and IEEE attests to the quality of the program being offered.

FUTURE AIR FORCE NEEDS

The dynamic change in technology affects many applications in society. Present-day research suggests that these technologies can apply to virtually every area using new-generation computing systems (22:41). The future Air Force needs are no exception because officers will use integrated management information systems, new computer architectures, and improved man-machine interfaces to perform their jobs.

"Integrated management information systems include conventional data base systems; expert, or so-called knowledge-based, systems; and multimedia information systems combining text, graphics, images, voice, and conventional data" (22:41). Knowledge of integrated management information systems (MIS) is necessary for future Air Force officers who use these systems for strategic planning and decision making. Strategic and tactical planners need a sophisticated information system to develop raw data into more meaningful information. This type of information system in strategic planning has an important role in command, control, and communication (C3). This may be the greatest role in the new generation computers with which Air Force officers must be familiar. Since the increasing complexity of logistics, i.e., supplies and support, as well as strategic and tactical planning ultimately determine the combat effectiveness of the Air Force, future Air Force officers require background in management information systems (22:44).

The Air Force needs computer engineers with an innovative computer architecture background. Computer architecture is the way various computational elements are interconnected to achieve a computational function. A parallel architecture, such as moving many bits of data at the same time, for analyzing radar and sonar is certainly expected for future weapons systems (22:44). Furthermore, a parallel processing architecture is expected in communications systems of the future. Embedded computer systems will require the most advanced skills for future computer architecture applications (22:44;23--).

The man-machine interface of future systems will become less cumbersome because most new generation computers and systems will support artificial intelligence applications. In artificial intelligence applications, software is now being developed for Air Force application in the areas of "speech, vision, natural languages, very large knowledge bases, graphics, and navigation"(22:54). These language applications need officers to work with real-time processing systems. The real-time processing systems are the only systems which can support the application areas since the languages require an enormous amount of computation. These applications will enhance the efforts to

introduce these systems to navigation and piloting systems in future aircraft (22:54).

This section has discussed computer technology trends. The rapid change in technology forces today's students to have the knowledge and exposure to future systems. For hardware, the trend is toward faster computation, a more compact size, and much less expensive devices. Due to the trends, educational programs must change. The change for education is in development and maintenance of a state-of-the-art curriculum in engineering schools. This flexibility in a curriculum ensures that the student will have a viable and current engineering education. Future Air Force officers must be familiar with management information systems for strategic decision making, new computer architectures for embedded computer systems, and artificial intelligence for real-time processing systems. Since some of the future Air Force officers will be Academy graduates, they must be prepared with a background in computer engineering. For these reasons, the Air Force Academy must consider the computer engineering discipline as part of the curriculum.

CHAPTER THREE

COMPUTER ENGINEERING AND THE ACADEMY

"The mission of the Air Force Academy is to provide instruction and experience to all cadets so that they graduate with the knowledge and character essential to leadership and the motivation to become career officers in the United States Air Force" (58:1). This mission statement provides a framework for the Air Force Academy's curriculum. The curriculum gives each cadet a well-balanced program which provides the graduate a solid foundation for an Air Force career (58:1). In this section, a discussion of the academic mission of the Academy, current Air Force programs, and the Air Force need for an Academy input to the Air Force officer mainstream is given.

THE ACADEMY AND ITS ACADEMIC MISSION

The Air Force Academy program has three aspects: military, athletic, and academic. Each aspect is a part of the professional development program which provides a cadet with the knowledge, skills, values, and behavior characteristics to develop leadership attributes. The aspects of the academy program divide the cadet's time between the three mission elements. The military slice of cadet time comprises twenty-five percent. During this time, leadership is stressed through squadron and wing positions. Secondly, athletics take ten percent of the cadet's time. The main objective under the athletics mission element is physical fitness training. Finally, in addition to the cadet's discretionary time of fifteen percent, academics are allotted fifty percent of the cadet's time. In this mission element, a cadet is challenged in professional development, military studies, aviation, and the academic program. Since the academic curriculum has a broad scientific and engineering base, each cadet receives a Bachelor of Science degree upon graduation as well as a commission in the regular Air Force (58:10-11).

The Academy academic program has the following objectives:

-- To provide cadets with general courses in the basic sciences, engineering sciences, social sciences, and humanities to form a foundation for their future development as Air Force officers.
-- To offer elective courses to meet the needs of each cadet's academic major.
-- To motivate the cadet toward advanced education through enrichment courses.
-- To prepare cadets to fulfill their intellectual responsibilities as citizens and dedicated public servants in the Air Force (54:1-1).

Each cadet's program consists of a set of prescribed core courses, majors courses, and flight core. The core courses represent 37 out of a possible 49 total courses which are taken. For those who chose to major in an area, cadets enroll in 9 or 11 departmental major's courses in addition to the core. Each cadet enrolls in one course unit of flight core. For emphasis here, the 11 disciplinary majors in science and engineering are listed in TABLE 2 on the following page. Other majors are listed and total as follows with six in Social Sciences and Humanities, two interdisciplinary, and four divisional (58:46).

The following statement explains the accreditation criteria for the Air Force Academy which is taken from the catalog:

> The Air Force Academy is a fully accredited institution of higher learning. The standard Bachelor of Science degree is accredited by the North Central Association of Colleges and Schools (NCACS). The Accreditation Board for Engineering and Technology (ABET), composed of representatives of the major professional engineering societies, has granted accreditation to the majors in aeronautical engineering, astronautical engineering, civil engineering, electrical engineering, engineering mechanics, and engineering sciences. The major in chemistry fulfills the recommendations of the Committee on Professional Training of the American Chemical Society" (58:49).

In summary, the academics at the Air Force Academy is biased toward the technical. Although, several social science and humanities majors exist, each cadet receives the Bachelor of Science degree. The core courses are required for all cadets. The mandate from the Academy and the Air Force is that officers need a scientific and technical background and the experience to prepare for future leadership responsibilities. The leadership

attributes acquired by a cadet are used to guide the engineering and management of Air Force programs.

DISCIPLINARY MAJORS SCIENCE AND ENGINEERING	
Civil Engineering	Mathematical Science
Computer Science	Physics
Electrical Engineering	Aeronautical Engineering
Engineering Mechanics	Astronautical Engineering
Engineering Science	Biology
Chemistry	
SOCIAL SCIENCE AND HUMANITIES	
Behavior Sciences	History
Economics	International Affairs
Geography	Management
INTERDISCIPLINARY MAJORS	
Operations Research	Aerospace Sciences
DIVISIONAL MAJORS	
Basic Sciences	Engineering
Humanities	Social Sciences

TABLE 2. Air Force Academy Academic Majors

CURRENT AIR FORCE PROGRAMS

The United States Air Force is the primary aerospace arm of the nation(61:v). Because of this, the Air Force is challenged to meet the threat to our nation's peace. Further, a modern and

expanding force is necessary for the future. Because aerospace power is a critical element to provide our nation a deterrent to aggression, current Air Force programs must counter Soviet nuclear forces, and be ready, sustainable, and modern(60:--). In this section, the discussion centers on current Air Force programs and the impact Air Force people have on their success toward being a credible deterrent.

The Air Force defense posture centers around three goals: "to increase combat capability; to reduce the average age of the force; and, to permit a modest force expansion" (60:160). Combat readiness and sustainability are critical elements of a credible deterrent. "Combat readiness is determined by the amount and type of equipment and supplies on hand, as well as by personnel and training levels" (60:159). The quality of Air Force people is crucial to the readiness posture. To sustain forces requires the ability to create reserves in spare parts and munitions (63:1-6). Logistics enhances the sustainability effort. A computerized management information system can ensure sound practices occur in the management of these resources and also maintain accurate inventories for munitions and spares (60:1-19:63:1-6). The bottom line for readiness, sustainability, and a capable force structure is an innovative, well-trained cadre of people with backgrounds coupling technology and combat effectiveness.

In summary, the aerospace force acts as a crucial element toward deterring aggression. The modernization effort will create weapons and command, control, and communications (C3) systems which will enhance combat capability for the future. As a result, the Air Force can meet many challenges and address issues by an upgrade to levels which enhance capabilities, act as a deterrent, and result in keeping the peace. It is evident that Air Force personnel with highly sophisticated backgrounds are needed to manage, design, and build these systems.

AIR FORCE NEED FOR COMPUTER ENGINEERING AT THE ACADEMY

Graduating as an Air Force officer from the Air Force Academy leads to rapidly expanding professional opportunities. Each year the Academy commissions approximately one thousand second lieutenants. Most graduates go to pilot training, but approximately 30% go to non-flying mission support career assignments (58:13). This section discusses the needs of the Air Force with respect to the computer engineering curriculum since leadership, technology, and other requirements drive the Academy program.

The fast-growing computer engineering discipline has been impeded by formal curriculum changes. The trend toward computer technology affects many areas of the present curriculum. Weapons systems and command, control, and communications (C3) systems rely on computer technology. It is implied, then, that military educational institutions provide future leaders with an appropriate curriculum.

The Air Force Academy is a leader in academic excellence. The Academy academic program allows cadets the fullest and broadest education possible in basic and engineering science and the social sciences and humanities (58:45). The Academy Board of Visitors (BOV) stated in May 1984:

> The academic curriculum continues to be a well-balanced program that provides a broad foundation for future Air Force officers. The Board supports the core curriculum as the base of the cadet's education. The members view the balance between basic and engineering sciences and the humanities and social sciences as appropriate. The Academy's effort to introduce interdisciplinary and space related courses shows its forward-looking approach to education. The Board supports the Academy's evolutionary approach to academic change (57:23).

The Board allows for academic disciplines to emerge in order for the Academy to maintain status in the nation as a leading academic institution. The BOV further stated "the Academy should be among the leaders in academic instruction" (57:23). This is another reason computer engineering should be considered as an academic discipline at the Air Force Academy.

The trend toward rapidly changing computer technology is threatening to the current Air Force Academy engineering program. Many educational institutions lag far behind in the computer revolution due to the major impact of computer technology on education. Because the curriculum in the Academy engineering division generally follows state-of-the-art topics, the question develops concerning computer engineering. To maintain a framework in which to work and prevent obsolesence, it is imperative Academy Curriculum Committees examine the impact of computer technology on the engineering curriculum. To continue to graduate future officers with the technological background for handling the complexity of problems and sophisticated hardware of weapons systems of the future, the Academy must continually develop and maintain its curriculum. The suggestions to alleviate obsolesence and ensure a current academic program will aid the Academy to continue an educational base to support a dynamic technologically changing Air Force.

As stated earlier, the Air Force requires personnel with an educational background in computer engineering. As such, Major General Jasper A. Welch, Assistant DCS/Research, Development, and Acquisition, has stated that "the formal education background of personnel assigned to work these specialties [computer engineering] will be the foundation for success in this new and rapidly expanding career area. The scope of their background must include specific combinations of engineering, mathematics, and computer science courses" (70:--). Should the Air Force Academy program become exempt from this requirement? Certainly not. Future Air Force officers will plan, design, implement, and manage weapons systems and command, control, and communications systems heavily dependent on computer technology. Major General Welch says that these resources [weapons systems] must be absolutely managed properly (70:--). Therefore, the Air Force Academy cadet should be provided the opportunity for exposure to a computer engineering curriculum. The result as stated by General Robert T. Marsh, USAF (Retired), Commander Air Force Systems Command, will be a substantial new knowledge base held by these future officers, an expertise the Air Force needs, and an accessibility of quality personnel to fill an emerging technological field who have an engineering perspective in management (73:--).

In this section, we have stated the Air Force relies on computer technology as a basis for weapon and C3 systems. Since some Air Force leaders will manage weapons systems, the computer engineering discipline should be given as a choice among the majors. Because of the USAFA leadership in the nation as an academic institution, the BOV supports the Academy's evolutionary approach to academic change. This will assist in maintaining the Academy as a leading academic institution. Further, the Academy is challenged due to changing technology. To avoid an obsolete academic program, it must support the rapid change in technology by an innovative engineering curriculum. Finally, since the Air Force has a requirement for the computer specialties, the Academy is not exempt from offering this discipline. The Academy should provide the opportunity to future officers with the desire, skill, and qualities to pursue the computer engineering career field. A subtle responsibility given to the Academy via its mission is to provide instruction to cadets so that they have knowledge essential for leadership. This instruction allows those cadets with the potential to choose a highly technical field, excel in the subject area, and be the leaders of tomorrow's Air Force by their background and skill in engineering, mathematics, and computer science. The next chapter discusses the structure of the computer engineering degree and accreditation criteria.

CHAPTER FOUR

THE COMPUTER ENGINEERING DEGREE

This chapter describes USAFA computer engineering curriculum based on Department of Electrical Engineering Computer Engineering Task Force (CETF) and the IEEE Computer Society Model Program in Computer Science and Engineering. These two programs are compared to see how they meet Air Force Academy needs. For brevity, the assumption of this chapter and the rest of the report is that the administration of the computer engineering major will be under the Department of Electrical Engineering.

CETF PROGRAM FOR COMPUTER ENGINEERING

The structure for the computer engineering program option for the Department of Electrical Engineering is shown in Table 3 on the next page (69:Fig 1). The courses shown are major courses. The table includes core substitutes: Circuit Analysis, EE340, and Probability with Statistics, MA 357. The new courses needed to be developed according to CETF were entitled Computer Architecture, Discrete Structures and Modern Algebra, and Real-time Operating Systems (69:6). However, it is possible that an existing course entitled Computer System Organization, CS 351, may substitute for Computer Architecture. The two elective options must come from the list given in Table 4 (69:5). These options are for flexibility and variability. The complete major including core courses, major's courses, and flight core for the CETF program is shown at Appendix C (69:1-7).

CORE	Introduction to Computer Science	CS 100
	Digital Signals and Systems	EE 210
	Circuit Analysis	EE 340
	Probability with Statistics	MA 357
MAJORS CORE	Applied Electronics Circuits	EE 342R
	Advanced Digital System Design	EE 380
	Computer Architecture	EE 3XX*
	Programming Languages	CS 359
	Real-Time Assembly Language Programming	EE 487
	Discrete Structures and Modern Algebra	MA 3XX(N)+
	Software Design Methodologies	CS 453
	Real-Time Operating Systems	EE 4XX(N)*
	Microprocessor Systems Design	EE 488
	ELECTIVES	Options(2)

*CS 351 can substitute
(N)+ New Mathematics course
(N)* New Electrical Engineering course

TABLE 3. Structure for Computer Engineering Major from CETF (69:4)

HARDWARE EMPHASIS		
Electrical Engineering(EE)	341R	Solid State Devices
	EE 346	Signal and Systems Analysis
	EE 481	Instrumentation
Astronautics(Astro)	452	Linear Control System Analysis and Design
SOFTWARE EMPHASIS		
Computer Science(CS)	362	Computer Simulation
	CS 380	Algorithms and Data Structures
	CS 454	Systems Analysis and Design II
	CS 473	Embedded Computer Systems
MATH EMPHASIS		
Mathematics(MA)	330	Engineering Mathematics
	MA 341	Introductory Numerical Analysis
	MA 360	Linear Algebra

TABLE 4. Elective Course Options for the CETF Program in Computer Engineering (69:5)

IEEE COMPUTER SOCIETY MODEL PROGRAM IN COMPUTER SCIENCE AND ENGINEERING

The structure for the model curriculum from the IEEE Computer Society is detailed in three areas: core subject areas, advanced subject areas, and non-computer science and engineering areas (non-CSE). The core subject areas are shown in Table 5 (20:--;21:9).

> The subject areas are designed to provide a balance between hardware and software concepts through lecture/recitation classes reinforced by experimentation and projects in the laboratory component. A substantial laboratory component is included to refine problem-solving techniques through experimentation .... The intent of the project laboratory is to integrate the concepts in hardware and software through well-chosen applications (21:11).

The advanced subject areas are shown in Table 6 (21:11). "Advanced subject areas supplement the core for in-depth study in specific topics. Implementation of some of these subject areas may range from a portion of one or several courses to a sequence of complete courses, so core subject areas are replaced as advanced subject areas" (21:11). It is noted particularly that "no institution is expected to be able to include all of these areas in a curriculum. However, a program must include a sufficient number of courses from related subject areas to cover two or more areas of in-depth study" (21:11).

The model program lists subjects which are called professional electives (RPE). These subjects, listed in Table 7 (21:Table 4), are selected to develop an area of concentration in one of the CSE subfields. The "electives are typical, but the actual selection will be a function of the current interests of the faculty associated with the program" (21:11).

A structure using model program core recommendations is shown in Table 8 (21:Table 5). The courses are an example from a complete computer engineering major's program. The non-CSE aspect of this curriculum is listed in Table 9 (21:Table 6). These subjects conform to the ABET requirements for each category. The complete program is at Appendix D (21:15).

CORE LECTURE/RECITATION COMPONENT
Fundamentals of Computing
Data Structures
System Software and Software Engineering
Computing Languages
Operating Systems
Logic Design
Digital Systems Design
Computer Architecture
Interfacing and Communication
LABORATORY COMPONENT
Introduction to Computing Laboratory
Software Engineering Laboratory
Digital Systems Design Laboratory
Project Laboratory

TABLE 5. Core Subject Areas of the Model Program (21:9)

Software Engineering
Digital Design Automation
Theory of Computing
Database Systems
Advanced Computer Architecture
Design and Analysis of Algorithms
Fault-Tolerant Computing
Performance Prediction and Analysis
Computer Graphics
VLSI System Design
Translator Writing Systems
Computer Communications Networks
Systems Laboratory
Artificial Intelligence
Advanced Operating Systems

TABLE 6. Advanced Subject Areas of the Model Program (21:11)

STUD YEAR	PROF ELECTIVE	SOFTWARE ENGINEERING	COMPUTER SYSTEM DESIGN	KNOWLEDGE-BASED SYSTEMS
JR	1	Complier and Translators	Architecture	Database Systems
JR	2	Intro to Performance Analysis	Advanced Electronics	Theory of Computing
SR	3	Operating Systems	Computer Communications Networks	Operating Systems
SR	4	Database Systems	Operating Systems	Artificial Intelligence
SR	5	Theory of Computing	Compilers and Translators	Architecture
SR	6	Translator Writing Systems	Design Automation	Compilers and Translators
SR	7	Architecture	Intro to Performance Analysis	Computer Communication Networks
SR	8	Computer Communication Networks	VLSI System Design	Distributed Databases
SR	9	Design and Analysis of Algorithms	Fault-Tolerant Computing	Graphics

TABLE 7. Professional Electives by Subfield Area for the Model Program by Student Year (21:14)

SUBJECT AREA/COURSE TITLE	COURSE NUMBERS (SEE APPENDIX D)
1/Fundamentals of Computing	CSE 101, 102
2/Data Structures	CSE 101, 102, 201
3/System Software and Software Engineering	CSE 302
4/Computing Languages	RPE*
5/Operating Systems	RPE*
6/Logic Design	CSE 102, 201, 203
7/Digital Systems Design	CSE 201, 203, 301
8/Computer Architecture	RPE*
9/Interfacing and Communications	CSE 203, 301, 302
10/Intro to Computing Laboratory	CSE 101, 102
11/Software Laboratory	CSE 303
12/Digital Systems Design Lab	CSE 203
13/Project Laboratory	CSE 401, 402

*Required Professional Elective

TABLE 6. A Model Program Core (21:15)

REQUIREMENT	SUBJECT	COURSE NUMBER (SEE APPENDIX D)
1/2 Year	Mathematics	Math 101, 102, 201, 202; Statistics 301; CSE 202
1/2 Year	Basic Sciences	Chem 101; Phys 101, 102; Basic Science Electives
1/2 Year	Humanities/Social Sciences	Humanities Social Science Electives
1 Year	Engineering Sciences	EE 201, 301; ES 301; CSE 101, 102, 301; Professional Electives(Table 7)
1/2 Year	Engineering Design	CSE 101, 102, 201, 202, 301, 303, 401, 402

TABLE 9. ABET Non-Computer Science and Engineering Requirements (21:5)

INCORPORATING THE MODEL PROGRAM INTO THE AIR FORCE ACADEMY PROGRAM

In this section, a discussion of the program criteria and the rationale for adding a new course to the Academy curriculum is presented. The guidelines set by ABET are the basis for the example. Since ABET is responsible for monitoring, evaluating, and certifying the quality of engineering and engineering-related education in colleges and universities in the United States, this criteria is presented as a set of rules. ABET "performs a qualitative and quantitative analysis of a school's program content to ensure that it meets the minimum criteria for mathematical foundations, basic sciences, engineering sciences, engineering design and synthesis, and humanities and social sciences" (1:3). Most of these subjects are clearly defined and accepted widely among institutions (69:4-1). However, the definitions for engineering sciences and engineering design vary in scope and origin. For this reason, the definitions, as established by the accrediting programs in engineering, are given here (11:6):

Engineering Sciences - "A body of knowledge or study which contributes to the students' abilities to apply basic science knowledge and skills to solve constrained classes of engineering problems involving a deterministic finite solution set" (11:6;69:Atch 4). Engineering sciences are generally taught at the analysis and applications levels of the learning taxonomy (5:120,144).

Engineering Design- "A body of knowledge or study which contributes to the students' abilities to apply basic and engineering sciences knowledge and skills to solve classes of unconstrained engineering problems with option and tradeoff decisions involving a generally unbounded set of solutions"(11:6;69:Atch 4). Engineering design is generally taught at the analysis, synthesis, and evaluation levels of the learning taxonomy (5:144,162,185).

These definitions assisted in the overall assessment of courses according to the categories. However, note that the ABET definitions and curriculum criteria both allow considerable latitude in their interpretation (25-28:--;76:--). Therefore, the assessments made in this analysis are generally subjective and based on individual knowledge, background, and experience.

PROGRAM CRITERIA

ABET Board of Directors revised the criteria for accrediting programs in engineering in October 1984 (11:1). In some cases, this criteria changed the CETF general requirement and the data listed in TABLE 9. The revised criteria give direction, although general in nature, for engineering programs (11:5). (Note: In the statements which follow one-half year is considered 16 semester credit hours). The general criteria for objectives and content which ABET expects are

1. The equivalent of at least three years study in the areas of mathematics, basic sciences, engineering sciences, engineering design, and the humanities and social sciences. The coursework must include at least
   a. One year of an appropriate combination of mathematics beyond trigonometry and basic sciences which includes general chemistry and physics,
   b. One year of engineering sciences,
   c. One-half year of engineering design, and
   d. One-half year of humanities and social sciences.
2. Appropriate laboratory experience,
3. Appropriate computer-based experience, and
4. Competency in written communication (11:5).

There are criteria revised by the IEEE and the Engineering Accreditation Commission (EAC) in the ABET report. One of the revised programs is for computer and engineering programs (11:14). The revised criteria for computer engineering programs are divided into four areas: applicability, curriculum, faculty, and institutional commitment and facilities.

1. Applicability - any program in engineering which has computer or a similar modifier in the title.
2. Curriculum
   a. Curricular objective and content; structure must provide in-depth study in
      (1) Computer science and
      (2) Engineering
   b. Mathematics
      (1) A strong mathematical foundation in:
         a) Differential and integral calculus,
         b) Discrete mathematics,
         c) Probability and statistics,
         d) At least <u>one</u> of the following:
            1) Linear algebra and matrices or
            2) Numerical analysis, and
      (2) Some mathematics may be treated in required computer courses.

c. Engineering Science and Design
   (1) One engineering science course outside the major areas of computer science and computer engineering.
   (2) Engineering science and design courses that provide a balanced view of:
      a) Hardware
      b) Software
      c) Application trade-offs
      d) The basic modeling techniques used to represent the computing process
   (3) Size and structure for advanced courses provide individual attention to each student.

d. Laboratory Experience
   (1) Strong laboratory sequence provides experience
      a) Problem solving
      b) Design
   (2) Introduces
      a) Hardware implementation
      b) Computer programming skills to the assembly language level
      c) Documentation skills needed to carry out part a) and b)

e. Computer use
   (1) Each student must have
      a) Proficiency in structured programming
      b) Ability to use several programming languages, and
      c) Proficiency in at least one modern language.
   (2) Experience with
      a) At least one major operating system
      b) Documentation of software.

3. Faculty
   a. Size of faculty - At least five experienced, full-time members primarily committed to the program.
   b. Faculty qualifications - Competence must span the broad range of hardware and software interests associated with computer science and engineering.
   c. Teaching loads - Allow sufficient time for faculty professional development and growth activities such as
      (1) Research
      (2) Instructional innovation
      (3) Consulting
      (4) Publications
      (5) Related professional activities

4. Institutional Commitment and Facilities
   a. Computer Facilities - Each student must have ready access, preferably by interactive terminals, to a large-scale computer facility

that supports a reasonable number of major languages and special purpose software systems.

b. Laboratory Facilities
   (1) Access to stand-alone mini and microcomputer systems allow student to experiment with
      a) System software
      b) Interfacing techniques
      c) Related problem areas such as
         1) Computer networking,
         2) Operating systems and
         3) Graphics

   (2) Laboratory facilities that support
      a) Digital systems
      b) Experimental study of computer architectures (11:14-15)

Using the program criteria, the assessment is made for courses in the computer engineering major. This report will use existing Air Force Academy courses which apply to the degree, and develop a structure for a complete four-year matriculation for a cadet. The total requirement for the Bachelor of Science degree in computer engineering is listed at Appendix F. The list of requirements differs from the CETF study requirements by allowing a present course, Operating Systems (CS 483), to be used as the major's course to satisfy Subject Area 5 from TABLE 8. However, the Department of Electrical Engineering should consult practicing Air Force major command engineers for evaluation of the course. Also, another mathematics course is shown entitled discrete mathematics. This course has a different criteria from the CETF; but, does satisfy the IEEE Model Program requirement. The topics for the course are outlined at Appendix G. In addition, a recommended text and objectives are given for this course. Before the course and text are included in the USAFA program, they must be approved by the curriculum committee (54:1-1). A discussion of the rationale for the new course is given in the next section.

RATIONALE FOR ADDING NEW COURSE AT USAFA

A new course is needed to complete the curriculum for the computer engineering option of the electrical engineering major. The course is discrete mathematics. Discrete mathematics concerns the subjects of finite-state machines and discrete mathematical structures. In this section, the course will be examined according to ABET criteria and the cost/benefit of the course.

First, the course completes the degree requirement according to the ABET criteria and the IEEE Model Program (9:8;11:14;21:8-17;25-28:--). From Tables 5, 7, 9 and Appendix C, the model curriculum for computer engineering includes a subject from the mathematical requirement in discrete mathematics, CSE 202. The purpose of the course is "toward developing theoretical tools suitable for describing algorithmic applications" (9:8). Although the ABET criteria is very broad and general, the criteria specifically describes this course (11:14).

Secondly, the cost and benefit to the present curriculum for approval of the course are three-fold. The discrete mathematics course benefits cadets majoring in mathematics, computer science, and electrical engineering (9:--;13:--;17:1;69:--;74:--). First, mathematics majors can use the discrete mathematics course to broaden their major. Second, computer science majors can use the course to enhance the programming skills taught concerning the foundation of counting and applications of Boolean algebra. And third, the electrical engineering major uses the course to develop group theory for computer design, group codes in computer systems, and basic models of finite-state machines. Each course would cost no more than one faculty position and an additional curriculum trade-off, i.e. one course, from the electrical engineering or mathematics department. Presently, there are no courses which would meet the criteria.

In summary, the flexibility of a curriculum will allow for easy maintenance and continued adaptability. Discussed in this rationale are some reasons for including a course in discrete mathematics in the USAFA curriculum. Initially, the course completes ABET requirements for the computer engineering degree. Next, the cost and benefit is in the interest of the present Academy program. Lastly, the Academy must have a viable, dynamic, and adaptable curriculum in its engineering department which is current for future Air Force officers. Professionally, these officers deserve an engineering degree which will give them a firm foundation and the tools to lead tomorrow's Air Force.

This section discussed the computer engineering degree. The initial section compared the model program for computer engineering to the CETF program. Next, the criteria established by ABET was discussed. This criteria gives a framework which surrounds the rest of the Computer Engineering program and meets standards and other criteria for accreditation.

CHAPTER FIVE

AN IMPLEMENTATION PLAN

This chapter describes a recommended implementation plan that could be used for the computer engineering major in the Department of Electrical Engineering. Considered in this plan are ABET requirements for the computer engineering degree and the IEEE Model Curriculum criteria. In addition, manpower and facilities, course sequencing and scheduling for the Academy mission, timing for accreditation of the computer engineering degree, and issues of the CETF study are addressed. Several unresolved issues are discussed and should be considered before seeking to incorporate the major at the Air Force Academy.

THE STRUCTURE OF THE COMPUTER ENGINEERING PROGRAM

The implementation structure is shown at APPENDIX E using the model curriculum as the strawman (9:3-6;21:14). The implementation structure is a semester-based program consisting of 49 units or 147 semester hours. It includes the 37 core units, 11 majors course units, and one unit of flight core. As discussed earlier, the requirements structure shown at APPENDIX F easily fits the IEEE model curriculum and satisfies the criteria. The mapping of the IEEE model program core is shown in TABLES 10 and 11. The option shown in the tables is for a hardware specialization. Other specializations are possible in software or mathematics using the electives options shown at APPENDIX F. These are the electives discussed in TABLE 4.

RQMNT(YRS)	SUBJECT	COURSE NUMBERS	TOTAL HRS
1/2	Mathematics	Math 131, 132, 133, 211, 357, Math 3XX+	18
1/2	Basic Sciences	BioSci 110, Chemistry 101, 102; Physics 211, 311, 411	16.5
1/2	Humanities/ Social Sciences	BehSci 110, Engl 111, 212, 330, 406; Econ 221, 222; Hist 101, 202, 303; Law 300, 400; Phil 310; PolSci 200, 201, 203, 310, 412	34.5
1	Engineering Sciences	EE 210, 340, 344, 346, 371, 380, 471, 481, 488, 489; Engr 110; CS 100, 351, 359, 453, 483; Aero 311, 312; Astro 332; Mech 210	38.5
1/2	Engineering Design	EE 210, 380, 471, 488, 489; CS 359, 453, 483; Engr 430; Mech 210; Astro 452	22.0

+Discrete Mathematics

TABLE 10. ABET Requirements for Non-CSE for Academy Computer Engineering Program with Hardware Emphasis

SUBJECT AREA	COURSE TITLE	COURSE NUMBERS
1	Fundamentals of Computing	CS 100, EE 210
2	Data Structures	CS 100, EE 488
3	System Software	CS 351, 359; EE 488
4	Computing Languages	RPE(+), CS 359; EE488
5	Operating Systems	RPE(+), CS 483; EE 488
6	Logic Design	EE 210, 380
7	Digital System Design	EE 210, 380, 488
8	Computer Architecture	RPE(+), EE 380, 488, 489; CS 351, 453, 483
9	Interfacing and Communication	EE 380, 488
10	Introduction to Computing Lab	EE 210; CS 100
11	Software Laboratory	EE 488; CS 359
12	Digital System Design Lab	EE 380, 488
13	Project Laboratory	EE 380, 488, 489, 464

(+) Required Professional Elective

TABLE 11. Mapping of the Computer Engineering Major with Hardware Emphasis to the IEEE Model Program

FACILITIES AND MANPOWER

Two issues addressed in the ABET revised programs by the Engineering Accreditation Committee(EAC) are facilities and manpower (11:14). The implementation of the computer engineering program can be supported with existing laboratory equipment in the Department of Electrical Engineering. Other equipment procured during Fiscal Year 85-86 merely adds to the department investment.

The present facilities include a laboratory for EE 210, Digital Signals and Systems, which has approximately forty educational computer (EDUCOMP) units. The Modern Logic Design course, presently EE 380, has twelve digital logic units (DLU) available. Both of these courses support a requirement for a partner team in the laboratories. The real-time computation and microprocessor systems courses use a small microcomputer by PROLOG corporation and the DLU. There are seventeen of these setups. In addition, two robot arms by the TEACHMOVER corporation and twelve NorthStar Advantage computers are used in these laboratory facilities. Recently, Intel Corporation donated a sophisticated Network Development System (NDS) to the department. The NDS system ties together a 35 million byte hard disk system and seven Intel floppy disk development systems (69:7). This system is earmarked for future use in the computer engineering area.

The department has access to several other resources such as the Burroughs, VAX, and Grimmell systems. These can be used for computer-aided learning or other study aids in any course. In addition, the Signal Processing Laboratory (SPL) has full access to the VAX for data processing, word processing and data collection. The SPL facility houses several terminals, graphics, and an analog-to-digital system for student and faculty use in the laboratory and for research. The end result is an existing laboratory with total facilities across the board which can support the computer engineering program.

In the area of manpower, the Department of Electrical Engineering is well staffed and has diverse expertise. "The implementation of the computer engineering program will not require an increase in the number of department faculty members" (69:7;73:--). Colonel Erlind G. Royer, Head of the Department, said that upon preparation for the accreditation visit for computer engineering, the department will use the same procedure for electrical engineering; and, he expects about a ten percent increase in effort (73:--). An anticipated and comparable drop in the electrical engineering enrollment will probably occur with the initial year of the computer engineering enrollment (69:7). This enrollment may affect faculty manpower requirements and should be examined. Another factor which may affect enrollment is the

degree of enrollment from outside the department, e.g., double and/or triple majors. This is not known at this time.

The department expertise is wide and diverse. In the department, there are eleven faculty members who hold doctorate degrees and twenty that hold masters degrees. Each faculty member has electrical engineering as their primary background; but, many specialize in diverse areas. For example, some faculty members specialize in signal processing while others are experts in communications theory. The list of topics for faculty expertise includes many subjects which cadets use for independent research (55:--;56:--). The list includes computer engineering, speech and voice processing, image processing, robotics, instrumentation, electronics, solid state physics, bubble memories, electromagnetic fields, systems analysis, and control systems. These subjects are more than adequate to field the wide interest which a student may have in computer or electrical engineering. As a result, each student has exposure to a faculty with wide experience, diverse backgrounds, and professional expertise for the future Air Force officer.

In conclusion, facilities and manpower can support the computer engineering major in the Department of Electrical Engineering. The department is well equipped and staffed to satisfy ABET and Air Force Academy requirements for faculty members.

COURSE SEQUENCING

This section discusses a course sequence for the computer engineering major. Factors which influence the structure of the computer engineering curriculum at the Academy include the following:

1. The mission of the Academy and the accompanying constraint on the number of courses available for a departmental major.
2. Existing degree programs in electrical engineering and computer science at USAFA.
3. The education and skill requirements of an Air Force computer engineer.
4. Representative curricula of computer engineering programs at civilian institutions.
5. The IEEE computer engineering model curriculum program outline.
6. Accreditation guidelines developed by ABET(69:3).

Using the structure outlined at APPENDIX E, a course sequencing is developed at APPENDIX F. The advantages of this sequence over others are

1. It maintains an unbroken sequence of both hardware-related and software-related courses,
2. It covers all the basic material in mathematics, hardware, and software before entering the applications courses,
3. It provides flexibility in the senior year where it is more likely needed, and
4. It maintains all applicable computer science courses in the semesters they are currently taught(69:5).

The following section discusses the implementation of the course sequencing with present and future electrical engineering courses.

IMPLEMENTATION SCHEDULE

To implement a viable computer engineering major, an option to the electrical engineering major must first be structured. Since ABET requires at least "one student to have graduated from the program prior to the time of final accreditation," the computer engineering curriculum must remain a part of the electrical engineering curriculum until that time (3:10;77:--).

To assist in reorganizing courses, the staff of the Computer Division of the Electrical Engineering Department developed the plan at APPENDIX I for revising electrical engineering courses (59:--). These revisions are to be implemented in Spring semester 1986. The course revisions were EE 388 replaces EE 380 and EE 488 replaces EE 487 and EE 488. This course (EE 488) starts where EE 388 leaves off. In addition, EE 489 is a new course in computer engineering. Another change is the revised EE 341 and EE 342, Electronics I and Electronics II, respectively (69:3). A curriculum change proposal (CCP) for renumbering these courses has been submitted. Finally, several other changes are affected. EE 342 in revised form becomes EE 471 for the Class of 1987. The sequence now becomes EE 340 to EE341 or EE 344, then EE 471. This sequence can be met under the Academy program by the previous structure developed at APPENDIX E.

The discrete mathematics course structure is shown at APPENDIX G. In an interview, Major Jim Crowley, Associate Professor, Mathematical Sciences at USAFA, revealed a discrete mathematics course presently being researched (75:--). The Department of Mathematics is developing a CCP for a Fall 1985 offering. The Mathematics Department anticipates mathematics, computer sciences, and electrical engineering disciplines will need this course (75:--). With this course available, cadets in the Class of 1987 can enroll with the appropriate prerequisites. As a result, these cadets could acquire a substantial part of the

computer engineering option. Also, with the Department of Mathematical Sciences teaching this course, the Electrical Engineering Department does not have to use manpower nor find expertise in this area.

In summary, this implementation has suggested that the computer engineering major begin as an option to the electrical engineering major. The first class for which the degree can be considered is the Class of 1987. This will be discussed in a latter section under the timeline requirements by ABET. In the next section, considerations for accreditation of the major are discussed.

ACCREDITATION OF THE ELECTRICAL AND COMPUTER ENGINEERING MAJORS

This section discusses the accreditation of the electrical and computer engineering majors. There are two alternatives to be considered for the computer engineering major:

1. Accreditation of the electrical engineering curriculum with computer engineering as an expanded track or
2. Accreditation of the computer engineering major separately.

In this section, the two alternatives are examined. The discussion examines the computer engineering major in accordance with ABET guidelines on accreditation. To facilitate this discussion, the following is assumed:

1. The mission of the Academy and the accompanying constraint on the number of courses available for a department major will not change.
2. The desire to maintain an accredited program under ABET for the existing electrical engineering major degree program.
3. The desire to acquire accreditation of a computer engineering degree program under ABET by the next accreditation cycle year the electrical engineering major is identified for such, i.e. 1990.
4. There will be at least one graduate in computer engineering before requesting accreditation of the computer engineering major.
5. The program criteria check list at APPENDIX J can be completed with positive results.

For the reasons discussed in Chapter Two, the computer engineering program should be accredited. Further, the Air Force Academy is an accredited institution with the Bachelor of Science degree accredited by the North Central Association of Colleges

and Schools (NCACS) and Accreditation Board for Engineering and Technology (ABET) granting accreditation to all of the Academy engineering division departments (58:49). Since all other engineering majors are granted accreditation, computer engineering should be accredited.

Chapter Five outlined the criteria and discussed how they fit the Academy needs. The program described in computer engineering is innovative, stimulating, and will encourage a creative and imaginative program. Accordingly, the student will gain a more than adequate foundation in the subject areas.

Under the first alternative, each cadet graduates as an electrical engineer. Because of this, the requirements listed at APPENDIX H must be met. However, for accreditation of the computer engineering option, the major cannot be constrained to 11 course units of major's courses. Depending on the student, one may require 12 or 13 units for a program in computer engineering. This may be realized with overloads, summer course enrollments or special academic programs in the four-year Academy program (12:--;54:Chap 3 and Chap 4). A suggested variation, and much more flexible, would be to substitute or revise the core course program. A substitution could be accomplished in mathematics, e.g., discrete mathematics for probability and statistics. There are many variations which add flexibility to the program and still meet accreditation criteria. Further, another idea is to revise the core. One variation here is to use any "seven" mathematics courses instead of the specified "core math." Any other mathematics course would logically be a higher level and would require some entrance policy, i.e. prerequisites to be met. The idea here is to allow any group of courses to meet the same criteria of the core mathematics.

Since each cadet is an electrical engineer with a computer engineering option, accreditation need not occur until 1990. This is due to the Department of Electrical Engineering evaluation by ABET during 1984. Each cadet can continue to enroll and elect the computer engineering option courses as part of the electrical engineering degree. However, when at least one has graduated, according to assumption (4) above, accreditation may be requested for the electrical engineering degree with the computer engineering option (3:10). The following explanation is taken from the current procedures guide for accreditation:

> An institution shall inform ABET as soon as possible when it changes the title or content of an accredited program. ABET determines if the program remains unaltered in content and continues to lie within the same professional discipline. If so, no further evaluation or action shall be required. When the new title or content alters the basis upon which the program was initially accredited, it shall be treated

> as a new program seeking accreditation and the appropriate procedures for such evaluation shall be followed (3:14).

This, in essence, allows for a name change in a program or content. Which triggers a reevaluation by ABET. In this case, with the entry of the computer engineering option to the Air Force Academy, the Department of Electrical Engineering could request an evaluation in two to three years. Until that time, cadets will continue to graduate with an accredited electrical engineering degree.

To address the second alternative, each cadet graduates as a computer engineer. The first student from the computer engineering major is possible from the Class of 1987. The Class of 1987 will declare their majors by March 1985. It is possible to recruit members who may want to be electrical engineers to enroll as computer engineers. The policy from the criteria for accrediting programs reads as follows: "Grant initial accreditation only if students have graduated from a program prior to the on-site visit, such accreditation to extend to the graduates of the program in the academic year prior to the visit" (11:3). This means the final report from ABET would not occur until October 1987. In general, unless a significant event occurs to delay administration or visits, the first class from computer engineering can be in two years from the original request from the Academy.

The title of the program is to be computer engineering. The program has to be descriptive of the content. The title for the program does not have to be too involved (11:3). As a matter of fact, "ABET discourages the proliferation of engineering program titles" (11:3). The concern here reflects the confusion or misleading guidance to students, the public and to employers (11:3). A simple and clear title will designate the program for the student's transcript. Finally, the title designation must be formal and completed prior to request to ABET for evaluation.

Therefore, to meet alternative two the criteria must be completed for the computer engineering major. A student has to have graduated from the discipline under the program title computer engineering (11:3). An accelerated schedule could be met if received by ABET in December 1985. A further discussion of timelines and schedules follows.

This section describes significant events for an accreditation cycle and the schedule for informing ABET (8:--). These procedures must be followed. The reason the schedule must be adhered to is that every participant needs an adequate allowance of time to perform a task (3:15). Upon notification, ABET will send materials to the Academy. If the Academy requests an evaluation in December 1985, then the questionnaire and

supporting documentation must be returned to ABET by 1 June 1986. Following the visit, the Board of Directors of ABET will take accreditation action by 1 July 1987. The complete report would be sent to the Academy by October 1987 (3:15). TABLE 12 outlines the schedule.

ABET TIMELINE FOR COMPUTER ENGINEERING	
Request for evaluation	By 31 Dec 85
Questionnaires returned	By 1 Jun 86
Visit scheduled	Between 1 Sep 86 to 31 Jan 87
ABET accreditation actions	By 31 Jul 87
Comprehensive reports	Between 1 Aug 87 to 31 Oct 87

TABLE 12. Schedule for 31 Dec 85 Initiation of Request for Accreditation for Computer Engineering (3:15)

IMPLEMENTATION ISSUES

There are several issues that must be resolved before having an accredited program in computer engineering at the Air Force Academy. Some of these issues involve Air Staff/Academy Board and Dean of Faculty level decisions which are not addressed in this study.

1. Does the Air Staff/Academy Board and Headquarters Air Force support USAFA with the implementation of the program in computer engineering?
2. Does the Dean of Faculty support a new major? Does the computer engineering major have Dean of Faculty approval?
3. Does the Dean of Faculty support new courses which are needed for the computer engineering degree?
4. Are the Academy permanent professors in concensus that the major in computer engineering is needed as a result of the findings?
5. What is the impact of this study's recommendation to pursue the Electrical Engineering degree with computer engineering options before attempting accreditation of the computer engineering major?
6. When will the Department of Electrical Engineering request accreditation for the computer engineering

major? Should the electrical engineering major be evaluated before 1990 with the computer engineering option?

7. Does the course Operating Systems, CS 483, satisfy the Air Force need for the background knowledge for the Academy computer engineering major?
   -- If not, can the Department of Electrical Engineering develop an operating systems course which will satisfy the need and maintain faculty to teach the course?
8. What is the impact on the Computer System Air Force Specialties when the 49XX AFSC is accessed?

Several other issues were presented to be addressed in this study from Chapter One. These issues are discussed here.

ISSUE 1. There is no impact on any computer science courses. Each course is a definitive part of the Academy academic program.

ISSUE 2. The Electrical Engineering Department expects a ten percent increase in load due to shifting enrollment. There is no impact to the advisor-in-charge staff in the department.

ISSUE 3. The Mathematics Department is currently preparing a discrete mathematics course for offering in Fall 1985. The curriculum change proposal is to be prepared for January 1985. The course is developed for mathematics, computer sciences, and electrical engineering majors.

ISSUE 4. Chapter Six discusses the best option for the computer engineering major. The major should remain a part of the electrical engineering major until at least one cadet has graduated.

ISSUE 5. The computer engineering option should be evaluated by ABET after the Class of 1987 has graduated.

ISSUE 6. Graduate schools and scholarships are listed at APPENDIX K. Each school has an autonomous scholarship program. The catalogs referenced list fellowships, assistantships, and forms of stipends for students (34-52:--;64:--).

ISSUE 7. All laboratory courses in the computer sequence of courses have an embedded laboratory program. The courses Laboratory Techniques I, II, and III are part of the electrical engineering major's core. The department has concentrated laboratory activities into this sequence. Each laboratory is scheduled in the same semester as its appropriate theoretical course (see APPENDIX H).

ISSUE 8. This issue relates to the revision criteria for accrediting programs (11:14). According to Dr. Edwin Jones,

Professor of Electrical Engineering, Iowa State University, ABET creates broad and general statements to allow the flexibility for a creative program for the student (76:--). This particular statement was given by the IEEE/EAC. According to Dr. Jones, this criteria suggests a high level of study in advanced subject areas 14 and 16, i.e., software engineering and theory of computing, respectively (see TABLE 7). Dr. Jones further emphasizes that these levels imply advanced study beyond the introductory courses which generally means advanced courses of in-depth study at the junior-senior level (25:182-184;76:--).

ISSUE 9. The related questions are covered throughout the analysis report, e.g., what major commands need computer engineers? Number needed? (see Chapter Two).

CONCLUSIONS

FINDINGS AND RECOMMENDATIONS

This section summarizes this report. A list of findings is discussed. Following the findings, recommendations are given.

This report investigated the computer engineering discipline as a viable major for the United States Air Force Academy. It considered the Air Force need, the Academy input to the Air Force, and the Academy mission. The background discussed the Department of Electrical Engineering initiative to lead the Academy in specialty courses in computer hardware, software, and design some eleven years ago. Several complementary courses in software and mathematics are taught in the Department of Computer Sciences and Mathematical Sciences, respectively. This collection of courses is called the computer engineering discipline. As a result of the Electrical Engineering Department efforts with this curriculum and several commands, the Air Force developed a requirement for computer engineers.

In this report, it was shown that a computer engineer is one who specializes in designing, developing, installing, and testing embedded computer systems in aircraft, missiles, flight simulators, and command, control, and communications systems. This individual is shown to work with hardware systems and interfaces. This implied the person needs to know electrical engineering. In addition, this individual worked with software systems and interfaces. Therefore, this means the individual knew computer science. Further, the person is shown to know computer architecture and other digital architecture common to electrical engineering and computer science. This person also was a systems engineer. To the Air Force, this person was described as an engineer and manager of embedded computer resources who develops resources into Air Force weapon and weapon-support systems.

In addition, this individual was described as one working with embedded computer systems due to his/her ability. The embedded computer system was described as all computer equipment, documentation, data, programs, personnel and supplies necessary

to a defense system from the design, acquisition, or operations and support point of view. Embedded computer systems were shown to be the smart weapon systems and communications devices. Many high ranking Air Force commanders discussed their need for expertise in the engineering and managing of embedded computer resources.

The needs of the Air Force were addressed. The trend for high computer technology which brought about the need was discussed with its implications. The Air Force computer engineer was established on 30 April 1984. At that time, three specialty codes were established which were the computer research scientist, the computer system acquisition manager, and the computer systems engineer. Each specialty required the Computer Engineering discipline as part of the background for the particular position.

With the Air Force need defined, the paper discussed why the computer engineering discipline is necessary at the Air Force Academy. The mission of preparing leaders, the current technological need in Air Force programs, and the Air Force need and the Academy's input to the Air Force mainstream determined why the discipline must be taught at the Academy.

Following the discussion of the Academy mission, the computer engineering degree is described. The structure for the major is completed using the Computer Engineering Task Force Study and the IEEE Computer Society Model Program in Computer Science and Engineering. The computer engineering major is designed to meet those criteria and Air Force Academy needs.

An implementation plan for the major was described. The report discussed facilities and manpower. A description of present laboratories was given and the status of the faculty. The ABET timeline was considered and two alternatives schedules were given.

Finally, a list of issues was presented. These were key items that must be resolved prior to seeking to incorporate an accredited program in computer engineering at the Air Force Academy. The level of the solution to these issues was beyond the scope of this report.

FINDINGS

The following is a list of findings of the report:

1. The computer engineer is someone with the ability to work with embedded computer resources and systems.

2. Embedded computer systems are computer resources engineered into systems whose functions are more global than computation.

3. On 30 April 1984, the Air Force required new specialty codes for scientific and development engineers.

   a. Computer Research Scientist (2625).
   b. Computer Systems Acquisition Manager (2736).
   c. Computer Systems Engineer (2885).

4. These Scientific and Development Engineering career fields have over 1500 requirements for FY85.

5. The trend for current computer technology is to continue to develop new generation microcomputer chips which are faster, smaller, and less expensive.

6. The Air Force Academy has 17 disciplinary majors, two interdisciplinary majors, and four divisional majors.

7. The Air Force Academy is a fully accredited institution. The Bachelor of Science degree is accredited by the North Central Association of Colleges and Schools. The Accreditation Board for Engineering and Technology grants accreditation to the engineering departments.

8. The computer engineering option provides the student with

   a. A broad background in computer engineering,
   b. Courses comparable to any leading civilian university, and
   c. A firm background for graduate study.

9. The Department of Electrical Engineering has appropriate laboratory facilities and manpower for the ABET accreditation criteria.

10. Before accreditation can be granted, at least one student must graduate from the program.

11. A new mathematics course will be implemented in the Department of Mathematical Sciences in the Fall 1985, entitled Discrete Mathematics.

12. It is possible to graduate the first cadet in electrical engineering with the computer engineering option in the Class of 1987.

13. Many undergraduate and graduate programs exist with computer engineering as a major; however, there are only 31 such programs with accreditation from ABET.

RECOMMENDATIONS

The following are recommendations from this analysis:

1. That the Academy Board approve the computer engineering discipline and manage the major through the Department of Electrical Engineering.

2. That the Electrical Engineering degree with Computer Engineering option be offered to the Class of 1987.

3. That the name of the program be specified as soon as possible in accordance with the ABET criteria, item II.A.13.
   a. Prior to the granting of accreditation to computer engineering, use the name "ELECTRICAL ENGINEERING WITH COMPUTER ENGINEERING OPTION"
   b. After the Class of 1987 graduates, use the name "COMPUTER ENGINEERING."

4. That the Department of Electrical Engineering pursue cadet awards for the computer engineering major.
   a. Top computer engineering cadet.
   b. Professional societies.
   c. Other national computer engineering awards for outstanding students.

5. That the Electrical Engineering Department seek accreditation of the computer engineering option after the first graduate and any time subsequent to the Class of 1987.

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APPENDICES

APPENDIX A

OFFICER AIR FORCE SPECIALTY

COMPUTER SYSTEMS ENGINEER

1. SPECIALTY SUMMARY

Plans, manages, and conducts the design, development, installation, testing, modification, support acceptance, and analysis of computer technology in systems, subsystems, and equipment.

*2. DUTIES AND RESPONSIBILITIES

a. *Designs, develops, modifies, and tests the use of computer technologies in systems and subsystems.* Plans and implements methods, processes, and techniques supporting systems design to improve performance, reliability, and maintainability for aircraft flight programs, command, control, communications, and intelligence (C^3I), aircrew training devices, automatic test equipment (ATE), electronic warfare (EW), missile, space, armament and munition, and other weapons systems development and modification programs. Performs subsystem and system development, acceptance, and operational tests on computer technology in these systems and subsystems to determine operational suitability, performance characteristics, and deficiencies or failures. Formulates test and acceptance criteria and techniques to determine causes of deficiencies and propose corrective action. Recommends acceptance or nonacceptance of computer elements, configuration items, and end items in Defense systems. Maintains records pertaining to projects. Prepares technical reports including recommendations for additional research and development projects involving computer technology.

b. *Coordinates computer technology research programs, projects, and contracts.* Coordinates appropriate laboratories, acquisition organizations, test organizations, modification organizations, DOD agencies, and industry. Serves as representative on scientific and technical boards and committees.

c. *Plans and organizes computer research and development engineering programs.* Analyzes problems related to the design and development of computer resources integral to systems, using engineering and mathematical theories, models, and research findings. Engages in continuous development and modification, and establishes engineering programs to define, maintain, and improve performance, quality, suitability, reliability, maintainability, and interface capability of computer technology in systems. Translates operational requirements and system design into definitive computer subsystems and recommends implementing actions. Plans, manages, and conducts hardware, software, and system engineering trade studies. Prepares and evaluates plans and specifications, considering such factors as requirements, cost, maintainability, feasibility, interoperability, standards, and operations. Plans and conducts engineering design studies and monitors studies contracted to industry.

3. SPECIALTY QUALIFICATIONS

a. *Knowledge.* Knowledge is mandatory of systems and computer technology research, development, and acquisition policies, procedures, and management practices supporting Air Force systems, subsystems, and equipment.

b. *Education:*

(1) Undergraduate academic specialization is mandatory in computer engineering or in electrical engineering or electronic engineering (with emphasis in computer engineering or computer science) in a school with a program accredited by a nationally recognized accrediting body (such as the Accreditation Board of Engineering and Technology).

(2) Master's degree in computer engineering, computer science, electrical or electronic engineering, or mathematics is desirable.

(3) Completion of Air Force Institute of Technology Education with Industry program is desirable.

c. *Experience.* A minimum of 24 months' experience in computer resource programs or teaching appropriate to the academic field of specialization is mandatory. It is mandatory that this experience include planning and participating in project design, development, integration, and testing of computer technology in weapon systems and subsystems.

4. SPECIALTY DATA

a. *Grade Spread.* Second lieutenant through lieutenant colonel.

b. *Related DOD Occupational Group:* 4B

*OFFICER AIR FORCE SPECIALTY

COMPUTER SYSTEMS ACQUISITION MANAGER

1. SPECIALTY SUMMARY

Plans, evaluates, manages, conducts, and directs research and development, activities for acquisition and support of computer engineering programs, projects, and activities for computer technology in systems; performs managerial functions involving design, configuration management, integration, quality assurance, and test of systems, methods, and techniques.

2. DUTIES AND RESPONSIBILITIES

a. *Formulates, plans, and organizes computer technology research and development objectives and policies.* Formulates internal policies and procedures for computer technology design studies; developments, simulations, tests, and evaluations of aircraft flight programs; command, control, communications, and intelligence (C^3I), aircrew training devices; automatic test equipment (ATE); electronic warfare (EW); missile, space, armament and munition; and other projects, activities, systems development, and test facility requirements. Reviews programs and projects and determines detailed requirements for project commitments. Plans organizational structure, considering such factors as type of units and integration and coordination of activities. Determines technical personnel requirements for project commitments. Formulates and prepares budget estimates and justifications. Recommends establishment or modification of existing research, development, and acquisition projects and test facilities.

b. *Plans, organizes, and manages systems research and development activities in agencies engaged in the design, development, modification, and testing of defense systems, methods, processes, and techniques.* Plans, schedules, and allocates work. Maintains work flow data to meet deadlines and priorities. Analyzes requirements and capabilities to determine if existing systems, methods, test facilities, processes, or techniques are satisfactory, need modification, or if new ones need to be developed. Accomplishes or directs preparation of computer research and development programs, activities, key program documentation, and acceptance reports. Provides contractors with technical information and guidance. Evaluates theories, approaches, and methods of conducting work to expedite results. Monitors in-house or contractor computer engineering efforts. Serves as project officer or manager having cost, schedule, logistics, and engineering management responsibility for hardware/software interfaces, systems integration, and system support.

c. *Coordinates research and development activities and recommends acceptance or nonacceptance of material and concepts.* Coordinates establishment of research, engineering system, and test projects with directors and technical boards and committees. Prepares technical reports and recommendations, in consonance with current state-of-the art, for additional research and development projects; research, development, test, and engineering (RDT&E) facilities; and independent validation and verification (IV&V). Provides for interchange of project data with related technical activities. Directs preparation, review, and revision of documentation and maintenance and operating standards for material. Serves as representative on scientific and technical boards and committees. Serves as technical consultant. Maintains liaison with contractors, Air Force field organizations, Army, Navy, and other governmental agencies.

d. *Provides acquisition program support.* Performs acquisition program support role. Acts as liaison or focal point for matters concerning planning and policy for the development and acquisition of computer technologies used in systems.

3. SPECIALTY QUALIFICATIONS

a. *Knowledge.* Knowledge of Air Force computer resource acquisition, support, IV&V, and RDT&E policies, procedures, and management practices is mandatory.

b. *Education:*

(1) Undergraduate academic specialization in one of the following is mandatory for entry:

(a) Electrical or electronics engineering with emphasis in computer engineering or computer science in a school

program accredited by a nationally recognized accrediting body (such as the Accreditation Board of Engineering and Technology).

(b) Business management with emphasis on electrical or electronic engineering, computer engineering, or computer science.

(c) Mathematics or computer science with a minimum of 32 semester hours in electronic, electrical, or computer engineering areas.

(2) A master's degree in any of the above disciplines is desirable.

c. *Experience:*

(1) A minimum of 24 months' experience in performing such functions as formulating plans and policies, devising procedures applicable to broad computer engineering matters, budget preparation and planning, and scheduling of RDT&E organizations is mandatory.

(2) Full qualification in the Computer Systems Engineer (2885) or Computer Research Scientist (2695) specialty is desirable.

4. SPECIALTY DATA

a. *Grade Spread.* Major through colonel.

b. *Related DOD Occupational Group:* 5L

*OFFICER AIR FORCE SPECIALTY

COMPUTER RESEARCH SCIENTIST

1. SPECIALTY SUMMARY

Plans, manages, and conducts research and scientific programs that support the design, development, support, installation, testing, modification, acceptance, and analysis of computer technology in systems, subsystems, and other equipment.

2. DUTIES AND RESPONSIBILITIES

a. *Conducts and manages computer technology research.* Plans research projects in circuit/logic analysis and design, computer analog and digital electronic interfaces, measurement and instrumentation, software engineering and compilation, numerical processing, and computer system architecture. Constructs experimental models (including simulations), conducts experiments, devises instrumentation techniques to record test results, and translates analyzed results into design specification criteria. Coordinates computer technology research programs, projects, and contracts with appropriate laboratories, acquisition organizations, test organizations, modification organizations, DOD agencies, and industry. Serves as representative on scientific and technical boards and committees.

b. *Develops new concepts, methods, and techniques to store, manipulate, transform, and present information by means of digital computer systems.* Applies theoretical foundations of computer science, system architecture, software organization, and information structures.

c. *Plans, develops and refines methods, processes, and techniques.* Supports systems developments to improve performance, quality, reliability, and maintainability for aircraft flight programs, command, control, communications, and intelligence (C^3I), aircrew training devices, automatic test equipment (ATE), electronic warfare (EW), missile, space, armament and munitions, and other systems development and modification programs. Does basic research and development in new emerging technologies such as artificial intelligence, speech synthesis, communications, and computer components.

3. SPECIALTY QUALIFICATIONS

a. *Knowledge:*

(1) Knowledge of systems and computer technology research, development, acquisition, and support policies, procedures, and management practices for Air Force systems, subsystems, and equipment is mandatory.

(2) Knowledge of theory of computer science, digital system architectures, automated software design methods, mathematical and statistical science is mandatory.

b. *Education:*

(1) Undergraduate academic specialization in computer engineering, electrical engineering, or electronics engineering with emphasis on computer engineering or computer science in a school program accredited by a nationally recognized accrediting body such as the Accreditation Board of Engineering and Technology is mandatory for entry. Specialization in a nonaccredited program in computer science is acceptable if it reflects a minimum of 32 semester hours in electronic, electrical, or computer engineering areas.

(2) Master's degree in computer engineering, computer science, electrical or electronic engineering or mathematics with emphasis in computer engineering or computer science is desirable.

(3) Completion of Air Force Institute of Technology Education with Industry program is desirable.

c. *Experience:* A minimum of 24 months' experience in computer technology programs or teaching appropriate to the academic field of specialization is mandatory.

4. SPECIALTY DATA

a. *Grade Spread.* Second lieutenant through lieutenant colonel.

b. *Related DOD Occupational Group:* 4B

Introduction

Scientific Utilization Field (26)

*1. The Scientific Utilization Field encompasses the scientific research function associated with research and exploratory development in support of Air Force requirements. In general, it requires very specific and extensive educational preparation. Each specialty includes responsibilities for conducting or managing programs, projects and (or) activities established to perform research pertinent to that specialty. Research includes the functions of defining a problem, selecting a method of approach, performing experiments, accumulating and interpreting data, and publishing the results. Research management includes such functions as formulating, planning, fiscal programming, monitoring, evaluating, coordinating and administering programs, projects, and (or) activities. These specialties, excluding AFSC 2616, will be used when research management requires technical specialization and an appropriate academic degree in a particular specialty and (or) academic field. Scientific positions are primarily laboratory oriented; however, these specialties are found throughout the research and development (R&D) community and related areas.

2. AFSC 2616, Scientific Manager, will normally be limited to the identification of senior management positions where duties and responsibilities are broad in nature, commensurate with grade, and include management of multiple programs, projects or activities involving diverse scientific fields of endeavor.

3. Excluded from this field are functions dedicated to research on computer hardware and software. These specialties are found in the Computer Technology Career Area.

4. Functions requiring only a general knowledge of science or R&D operations are described under AFSCs 2724 and 2895.

APPENDIX B

ACCREDITED PROGRAMS IN IEEE COMPUTER GROUP

Computer Engineering

Boston University

Case Western Reserve University

Florida Institute of Technology

Illinois at Urbana - Champaign, University of

Iowa State University

Michigan, University of; Ann Arbor

Missouri-Columbia, University of

New Mexico, University of

Oakland University

Pacific, University of the

Purdue University

Syracuse University

South Florida, University of

Southern Massachusetts University

Tufts University

Wright State University

Computer and Information Sciences

Florida, University of

Operations Research and Computational Science

George Washington University

Computer and Information Systems

Illinois at Chicago, University of

Computer and Systems Engineering

Rensselaer Polytechnic Institute

Computer Science

Connecticut, University of

San Jose State University

Northern Arizona University

Washington University

Computer Science and Engineering

California State University, Long Beach

California, Berkeley, University of

Massachusetts Institute of Technology

Texas at Arlington, University of

George Washington University

Computer Systems Engineering

Arizona State University

Massachusetts at Amherst, University

Engineering Mathematics and Computer Systems

Central Florida, University

APPENDIX C

CETF COMPUTER ENGINEERING MAJOR

The requirements for a Bachelor of Science degree in Computer Engineering are

1. Thirty-seven course units of core courses with the following substitutions:

El Engr 340	Circuit Analysis (Substitute for El Engr 310)
Math 357	Probability with Statistics (Substitute for Math 220)

2. Eleven course units of major's courses as follows:

a.	El Engr 341(R)[1]	Electronics I
b.	Comp Sci 351	Computer System Organization
c.	Comp Sci 359	Programming Languages
d.	Math 3XX(N)[2]	Discrete Structures and Modern Algebra
e.	El Engr 380	Modern Logic Design
f.	El Engr 487	Real-Time Assembly Language Programming
g.	Comp Sci 453	Systems Analysis and Design I
h.	El Engr 4XX(N)	Real-Time Operating Systems
i.	El Engr 488	Microprocessor Systems Design
j.	Comp Engr Option	(See supplemental information below)
k.	Comp Engr Option	

NOTES:

(1) R = Revised version of existing course
(2) N = New course

3. One course unit - Flight Core.

Supplemental Information

1. The computer engineering elective options are satisfied by taking a two course sequence in one of the following areas of emphasis. Options are subject to meeting course prerequisites and advisor approval.

HARDWARE EMPHASIS	SOFTWARE EMPHASIS	MATH EMPHASIS
El Engr 342(R)	Comp Sci 362	Math 330
El Engr 346	Comp Sci 457	Math 341
Astro 452	Comp Sci 554	Math 360
El Engr 481	Comp Sci 473	

2. Suggested Sequence

4	5	6	7	8
El Engr 340	El Engr 341(R)	El Engr 380	El Engr 487	El Engr 488
Math 357	Comp Sci 359	Comp Sci 351	Comp Sci 453	El Engr 4XX(N)
	Math 3XX(N)		Elective*	Elective

* This computer engineering elective option may be taken in either the 5th, 6th, or 7th semester depending on area of emphasis chose, prerequisite requirements, and course load.

APPENDIX D

COMPLETE PROGRAM FOR MODEL CURRICULA
IN
COMPUTER ENGINEERING

STUDENT'S YEAR	FIRST SEMESTER COURSE	UNITS	SECOND SEMESTER COURSE	UNITS
Freshman	Chem 101 (Chemistry 1)	4	Physics 101 (Physics 1)	4
	Math 101 (Calculus 1)	4	Math 102 (Calculus 2)	4
	CSE 101 (Intro to Computing 1)	3	CSE 102 (Intro to Computing 2)	3
	English 101 (English Comp)	3	Humanities/Social (Electives)	6
	Humanities/Social Sciences (Electives)	3		
	Total =	17	Total =	17
Sophomore	Physics 201 (Physics 2)	4	Science Elective	4
	Math 201 (Calculus 3)	4	Math 202 (Differential Equations)	4
	CSE 201 (Intro Comp Eng 1) Hardware & Software Design)	3	CSE 203 (Intro Hardware Design Lab)	3
	CSE 202 (Discrete Structures)	3	EE 201 (Basic Circuits & Electronics)	3
	Humanities/Social Sciences Electives)	3	Humanities/Social Sciences (Electives)	3
	Total =	17	Total =	17
Junior	CSE 301 (Hardware System Design Lab)	3	CSE 303 (Software Eng)	3
	CSE 302 (Software Eng & Assembler Programming)	4	Engineering Science (Mechanics)	3
	Engineerng Science (Linear Systems Analysis)	3	Prof Elective (see Table 4)	6
		3	Elective	3
	Total =	16	Total =	15
Senior	CSE 401 (Design Lab)	3	CSE 402 (Design Lab)	3
	Prof Elective (see Table 4)	12 or 9	Prof Elective (see Table 4)	9 or 12
	Elective	3 or 6	Elective	6 or 3
	Total =	18	Total =	18

APPENDIX E

COMPUTER ENGINEERING STRUCTURE
WITH
HARDWARE EMPHASIS

STUDENT/CADET YEAR /RANK	FIRST SEMESTER COURSE	UNITS	SECOND SEMESTER COURSE	UNITS
Freshman/4°	Bio Sci 110	0.5	Beh Sci 110	1.0
	Chem 101	1.0	Chem 102	1.0
	CS 100	1.0	English 111	1.0
	Foreign Lang	0.5	Foreign Lang	1.0
	History 101	1.0	Math 132	1.0
	Math 131	1.0	Math 133	1.0
	Total =	5.0	Total =	6.0
Sophomore/3°	Beh Sci 220	0.5	Aero 311	1.0
	Econ 222	0.5	Econ 221	1.0
	El Engr 210	1.0	El Engr 340	1.0
	Engr 110	1.0	English 212	1.0
	History 202	1.0	Math 357	1.0
	Math 211	1.0	Physics 211	1.0
	Mgt 203	0.5	Pol Sci 201	0.5
	Pol Sci 200	0.5	Pol Sci 203	0.5
	Total =	6.0	Total =	7.0
Junior/2°	Aero 312	1.0	El Engr 346	1.0
	Beh Sci 330	0.5	English 330	1.0
	El Engr 341	1.0	Philos 310	1.0
	History 303	0.5	Physics 311	1.0
	Law 300	1.0	El Engr 380	1.0
	Mech 210	1.0	CS 351	1.0
	CS 359	1.0	El Engr 342	1.0
	Math (EE) 3XX	1.0		
	Total =	7.0	Total =	6.0
Senior/1°	Physics 411	1.0	Pol Sci 412	1.0
	English 406	1.0	Law 400	1.0
	Engr 430	1.0	El Engr 488	1.0
	El Engr 487	1.0	CS 483	1.0
	CS 453	1.0	El Engr 481	1.0
	Astro 332	1.0	Astro 452	1.0
			El Engr 964	1.0
	Total =	6.0	Total =	7.0

APPENDIX I

COMPUTER ENGINEERING MAJOR

The requirements for a Bachelor of Science degree in Computer Engineering are

1. Thirty-seven course units of core courses with the following substitutions:

El Engr 340	Circuit Analysis (Substitute for El Engr 330)
Math 357	Probability with Statistics (Substitute for Math 220)

2. Eleven course units of major's courses as follows:

a.	El Engr 341(1)	Electronics I
b.	Comp Sci 351	Computer System Organization
c.	Comp Sci 359	Programming Languages
d.	Math 3XX(N)(2)	Discrete Mathematics
e.	El Engr 388(2)	Modern Logic Design
f.	El Engr 488(1)	Microprocessor Systems Design
g.	Comp Sci 453	Systems Analysis and Design I
h.	Comp Sci 483	Operating Systems
i.	El Engr 489	Computer Engineering
j.	Comp Engr Option	(See supplemental information below)
k.	Comp Engr Option	

NOTES:

(1) R = Revised version of existing course (see Appendix H)
(2) N = New course (see Appendix G)

3. One course unit of Electives

Supplemental Information

1. The computer engineering elective options are satisfied by taking a two course sequence in one of the following areas of emphasis. Options are subject to meeting course prerequisites and advisor approval.

HARDWARE EMPHASIS	SOFTWARE EMPHASIS	MATH EMPHASIS
El Engr 344	Comp Sci 362	Math 330
El Engr 346	Comp Sci 380	Math 341
Astro 452	Comp Sci 454	Math 360
El Engr 471	Comp Sci 473	
El Engr 477		
El Engr 481		

2. Suggested Sequence

4	5	6	7	8
El Engr 340	El Engr 341	El Engr 388	El Engr 488	El Engr 489
Math 357	Comp Sci 359	Comp Sci 351	Comp Sci 453	Comp Sci 483
	Math 3XX(N)		Electives*	Elective

* The computer engineering elective option may be taken in either the 5th, 6th, or 7th semester depending on area of emphasis chosen, prerequisite requirements, and course load.

Major's GPA computation: Eleven courses used for major.

APPENDIX G

DISCRETE MATHEMATICS
NEW MATHEMATICS COURSE DESCRIPTION

Prerequisite: EE 210 or Department Permission

Course Description: Introduction to finite-state machines and discrete mathematical structures. Topics include foudation of discrete mathematics, groups and semi-groups, counting and enumeration, applications of Boolean algebra and group theory to computer design, group codes in computer systems, basic models of finite-state machines, state and machine identification experiments, regular expressions and machine specification.

Text Discrete Mathematical Structures and Their Applications, H. S. Stone

COURSE OUTLINE:	PERCENT OF COURSE
1. Foundation of Discrete Mathematics	20
2. Groups and Semi-Groups	15
3. Counting and Enumeration	15
4. Applications of Boolean Algebra and Group Theory to Computer Design	15
5. Group Codes in Computer Systems	10
6. Finite-State Machines	25

APPENDIX H

ELECTRICAL ENGINEERING MAJOR

The Electrical Engineering major provides an opportunity to study the electrical and electronic generation, transmission and processing of information. Emphasis is given to the fundamental concepts which find wide application in Air Force weapons and support systems. This program is of particular value to cadets who will pursue Air Force careers in research and development, communications-electronics, and operations. Cadets who successfully complete this major are awarded a Bachelor of Science in Electrical Engineering which is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology.

REQUIREMENTS:	Course Title and Descriptive Information
A. 37 course units of core courses with these subs:	See Chapter 2 for listings of core courses by class
El Engr 340	Circuits and Systems I (subs for EE 310)
Math 357	Probability with Statistics (subs for Math 220)
B. 11 course units of major's courses as follows:	
1. El Engr 341	Electronics I
2. El Engr 344	Circuits and Systems II
3. El Engr 346	Linear Systems Analysis
4. El Engr 443	Electromagnetics
5. El Engr 464	Design Project
6. Math 330	Fourier Analysis, Laplace Transforms, and Applied Vector Analysis
El Engr 350*	Laboratory Techniques I
7. El Engr 351*	Laboratory Techniques II
El Engr 352*	Laboratory Techniques III
8. El Engr Opt**	(See supplemental information)
9. El Engr Opt	
10. El Engr Opt	
11. Science Opt**	(One course unit offered by Basic Science or Engineering Divisions selected with approval of the Faculty Advisor)
C. One course unit of flight core.	

Suggested Sequence:

4	5	6	7	8
El Engr 340	El Engr 341	El Engr 346	El Engr 352	El Engr 464
El Engr 350	El Engr 344	El Engr 443	El Engr Opt**	Science Opt**
Math 357	El Engr 351		El Engr Opt	Flight Core
	Math 330		El Engr Opt	
	Physics 311***		Engr 430	

* Three one-semester hour labs. Cadet will receive one course unit credit upon completion of the three course laboratory sequence.

** See supplemental information, Note 3.

*** Prerequisite for El Engr 443.

Supplemental Information:

1. Cadets unable to complete El Engr 340 in the 4th semester may schedule this course in the 5th semester; however, this may require an overload.

2. The El Engr elective options are to be selected from the following lists of courses. Options are subject to meeting course prerequisites and to advisor approval. El Engr 495 (when offered) and El Engr 499 may serve as El Engr elective options with Department Head approval.

a. Class of 1986.

El Engr 342	El Engr 447	El Engr 471	El Engr 487
El Engr 380	El Engr 448	El Engr 477	El Engr 488
El Engr 388	El Engr 449	El Engr 481	Astro 452

b. Class of 1987 and subsequent classes.

El Engr 388	El Engr 449	El Engr 481	Astro 452
El Engr 447	El Engr 471	El Engr 488	
El Engr 448	El Engr 477	El Engr 489	

3. El Engr elective options and Science options may be taken in either the 5th, 6th, 7th, or 8th semester.

4. Major's GPA computation: Eleven courses used for major.

APPENDIX I

Reply To: DFEE Computer Division, 2475 21 Sep 1984

Subject: Computer Division Curriculum Changes

To: DFEE Curriculum Committee

1. The DFEE Computer Division submits this proposal for revisions in three courses offered by the Department of Electrical Engineering, in accordance with paragraph c(7) of the DFEE Curriculum Committee Charter. These revisions are to take place beginning in the spring semester, 1986.

2. **El Engr 388**, replacing El Engr 380, will combine digital design techniques with microprocessor hardware and software applications.

a. Proposed new course offering in Digital Systems Design.

b. See attached schedule.

c. Prerequisites: El Engr 210, El Engr 310 or El Engr 340, Comp Sci 100.

d. The proposed audience includes Electrical Engineering, Computer Science, and General Engineering majors.

e. Proposed Texts:

i. "The TTL Data Book for Design Engineers", by the Engineering Staff of Texas Instruments Inc.

ii. "Z80 Assembly Language Programming", by Lance A. Leventhal.

iii. "The Z80 Technical Manual", by Zilog Inc.

f. Recommend course be an EE option for EE majors.

g. This course will include ten labs, accounting for 25% of the student grade.

3. **El Engr 488** will be revised to cover microprocessor hardware and software issues together, rather than the current split of hardware and software between El Engr 487 and El Engr 488. This course will pick up where El Engr 388 leaves off.

a. Proposed revised course in Microprocessor Systems Design.

b. See attached schedule.

c. Prerequisite: El Engr 388.

d. The proposed audience includes Electrical Engineering, Computer Science, and General Engineering majors.

e. Proposed Texts:

i. "Z80 Assembly Language Programming", by Lance A. Leventhal.

ii. "The Z80 Technical Manual", by Zilog Inc.

f. Recommend course be an EE option for EE majors.

g. This course will include six labs, accounting for 25% of the course grade.

4. El Engr 489 will be a new course in computer engineering. It will look at the internal workings of a microprocessor (with emphasis on controller design and microprogramming), as well as investigate such modern concepts as parallel processing, array processing, and computer networks.

a. Proposed new course offering, Computer Engineering.

b. See attached schedule.

c. Prerequisite: Math 211, El Engr 388, completed or enrolled in El Engr 488.

d. The proposed audience includes Electrical Engineering, Computer Science, and General Engineering majors.

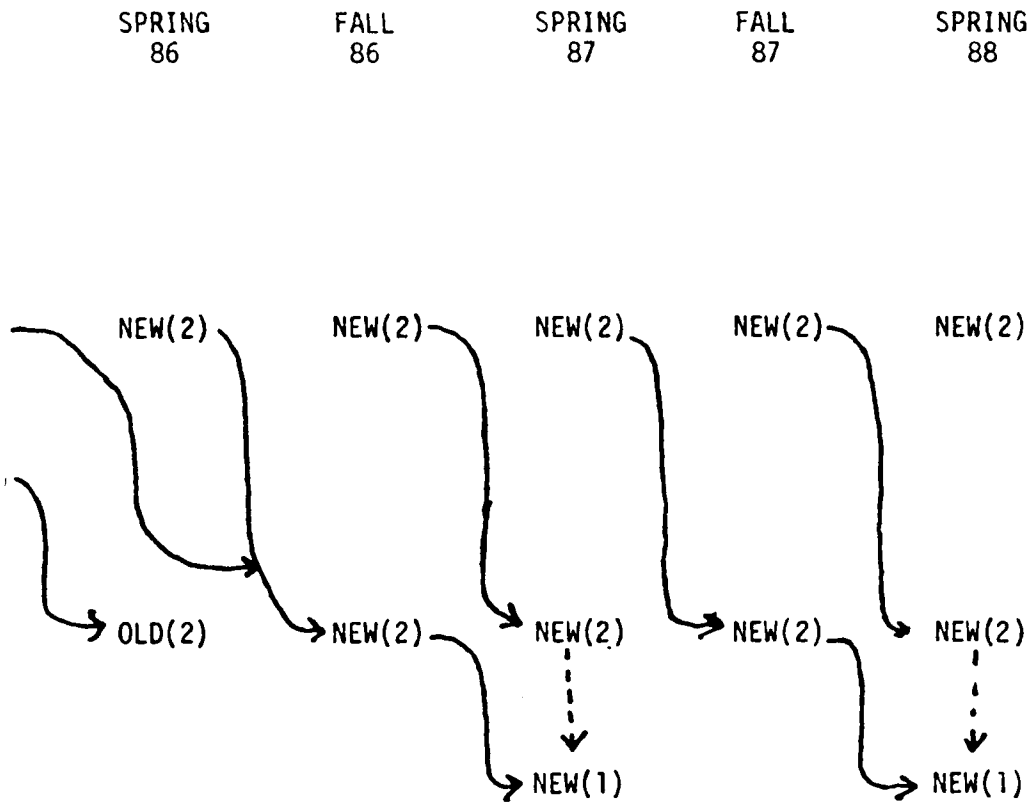
e. Proposed Text: See references, text to be determined.

f. Recommend course be an EE option for EE majors.

g. This course will include four labs, accounting for 15% of the student grade.

Paul

PAUL W. SCHOELL, Major, USAF
Chief, Computer Division, DFEE


SPRING 86
FALL 86
SPRING 87
FALL 87
SPRING 88
NEW(2)
NEW(2)
NEW(2)
NEW(2)
NEW(2)
OLD(2)
NEW(2)
NEW(2)
NEW(2)
NEW(2)
NEW(1)
NEW(1)

SCHEDULE

	ENGR SCIENCE	ENGR DESIGN
OLD EE 380	1.0	2.0
NEW EE 388	1.0	2.0
OLD EE 487	1.0	2.0
NEW EE 488	0.5	2.5
OLD EE 488	1.0	2.0
NEW EE 489	1.5	1.5
OLD TOTALS	3.0	6.0
NEW TOTALS	3.0	6.0

1. Curriculum Change Proposal _____. Change the course number, title, description and prerequisites of El Engr 380, Modern Logic Design.

2. Classes affected: 1987 and subsequent.

3. Effective date: Fall semester 1985.

4. Purpose and need for change: El Engr 380, Modern Logic Design, was a Medium Scale Integration (MSI) hardware-oriented course that provided little insight into Large Scale Integration (LSI) applications. The new course, El Engr 388, Digital Systems Design, will integrate MSI hardware and software to provide the insight needed to understand LSI microprocessor-based systems.

5. Description of change: Change course number, title, description and prerequisites of El Engr 380 to read:

El Engr 388. Digital Systems Design. 1(2)

An advanced course in the design of digital systems. Topics include a survey of modern logic families (TTL, ECL, CMOS), medium-scale combinational and sequential circuits, structured system design, microprocessor instruction sets, support software, and hardware-software relationships and techniques. Lab. Final Exam. Prereq: Comp Sci 100; El Engr 210; El Engr 310 or 340. Sem hrs: 3 fall or spring.

ERLIND G. ROYER, Colonel, USAF
Professor and Head, DFEE

1. Curriculum Change Proposal _____. Change the description , prerequisites, and offering time for El Engr 488, Microprocessor Systems Design.

2. Classes affected: 1987 and subsequent.

3. Effective date: Fall semester 1986.

4. Purpose and need for change: El Engr 488, Microprocessor Systems Design, was primarily a hardware-oriented course that depended entirely on a prerequisite course for the software. The new course will teach much of this software along with the hardware.

5. Description of Change: Change the description, prerequisites, and the offering time for El Engr 488 to read:

El Engr 488. Microprocessor Systems Design. 1(2)

Analysis and design of dedicated microprocessor systems. Includes Large Scale Integration (LSI) interfacing, computer architecture, hardware-software relationships, design methodology, and related laboratory techniques. Lab. Course Project. Final exam. Prereq: El Engr 388. Sem hrs: 3 fall or spring.

ERLIND G. ROYER, Colonel, USAF
Professor and Head, DFEE

1. Curriculum Change Proposal _____. Change the description, title, and offering time of El Engr 487 Real-Time Computation for Embedded Computers.

2. Classes affected: 1987 and subsequent.

3. Effective date: Spring semester 1987.

4. Purpose and need for change: This course will be the capstone course of the digital track in Electrical Engineering. The topics that were previously covered in this course will now be covered in two prerequisite courses, El Engr 388 and El Engr 488. This revised course will concentrate on computer engineering topics relevant to Air Force officers.

5. Description of change: Change description, title, and offering time of El Engr 487 to read:

El Engr 489. Computer Engineering. 1(1)

Fundamentals of computer engineering. Topics include microprogramming, computer arithmetic, high performance architectures, parallel processing, and distributed processes. Lab. Final exam. Prereq: Math 211, El Engr 388, completed or enrolled in El Engr 488. Sem hrs: 3 spring.

ERLIND G. ROYER, Colonel, USAF
Professor and Head, DFEE

EE 388 Proposed Syllabus - Fall 85

Digital Systems Design

	Lsn	Topic	Lab #
S	1	TTL databook	
S	2	Logic families, LAB protoboard	1
D	3	LAB fanout	2
2S 3D	4	MSI decoder, demux	
	5	MSI mux, encoder	
	6	MSI ROM, RAM, PLA	
	7	MSI registers	
	8	MSI counters	
D	9	LAB counters	3
D	10	MSI design, music synthesis	
5S	11	GR #1	
	12	Z-80 intro	
	13	Z-80 addr modes	
	14	z-80 assy language	
	15	Z-80 assy language	
D	16	Simple programs	
D	17	Debugging and testing	
D	18	LAB prolog familiarization	4
S	19	Z-80 assy lang, part 2	
D	20	Busses, tristate, open-collector	
D	21	Z-80 hardware, Z-80 bus	
	22	STD bus	

D	23	LAB Z-80 system signals	5
S	24	Memory intro	
D	25	GR #2	
D	26	Trouble-shooting	
D	27	LAB trouble-shooting	6
D	28	Z-80 subroutines	
D	29	LAB subroutines	7
S	30	Prolog monitor	
S	31	Development systems	
D	32	LAB Northstar familiarization	8
D	33	Parallel IO	
D	34	LAB stepper motor	9
D	35	LAB "	
S	36	Serial IO	
D	37	GR #3	
D	38	8251 IO chip	
D	39	LAB serial IO	10
D	40	LAB "	
D	41	LAB "	
S	42	Course review	

D FINAL EXAM

EE 488 Proposed Syllabus - Fall 86

Microprocessor Systems Design

Lsn	Topic	Lab #
S 1	EE387 review	
D 2	PASCAL/assy-lang interface	
D 3	LAB language interface	1
D 4	LAB "	
S 5	Z-80 timing review	
D 6	Memory timing	
D 7	LAB slow memory	2
D 8	LAB "	
D 9	Analog-digital	
D 10	Digital-analog	
D 11	LAB AD/DA	3
D 12	LAB "	
D 13	LAB "	
D 14	LAB "	
S 15	Course-proj/micro-talks intro	
D 16	GR #1	
D 17	Interrupts	
D 18	LAB interrupts	4
D 19	LAB "	
D 20	CRT/displays	
S 21	DMA-part 1	
D 22	DMA-part 2	

D	23	LAB DMA	5
D	24	LAB "	
D	25	Interval timers	
D	26	Preliminary final proj design review	
D	27	Programmable parallel IO chips/keyboards	
D	28	LAB PPIO	6
D	29	LAB "	
S	30	Microprocessor topics	
S	31	Floppy disk systems	
D	32	GR #2	
8D	33	Course proj work	
	34	Course proj work	
	35	Course proj work	
	36	Course proj work	
	37	Course proj demo	
	38	Prolog case study	
	39	Prolog case study	
	40	Prolog case study	
S	41	16/32-bit micro talking papers	
D	42	16/32-bit micro talking papers	
D		FINAL EXAM	

EE 489 Proposed Syllabus - Spring 87

Computer Engineering

	Lsn	Topic	Lab
S	1	Intro to computer engineering	
		BLOCK I - Microprogramming	
D	2	Controller Design	
S	3	Microprogrammed control orgranization	
D	4	LAB controllers	1
I	5	LAB "	
D	6	Interpreter design - stack machine	
D	7	Interpreter design - register machine	
		BLOCK II - Computer arithmetic	
S	8	Arithmetic - fixed point	
S	9	Arithmetic - floating point	
S	10	Lab system familiarization	
D	11	LAB arithmetic	2
D	12	LAB "	
S	13	IEEE floating point standard	
½S	½D 14	GR #1	

BLOCK III - High performance architectures

D	15	Buffering	
D	16	Pipelines	
S	17	Virtual Memory	
D	18	Paging, interleaving	
D	19	Cache	
D	20	Tasks and processes	
S	21	Interprocess comunication	
S	22	Scheduling	
D	23	"	
S	24	Performance evaluation criteria	
$\frac{1}{2}$S	$\frac{1}{2}$D	25 GR #2	

BLOCK IV - Parallel processing

S	26	Parallel applications	
S	27	"	
D	28	"	
D	29	Laboratory	3
S	30	Parallel processing	
D	31	"	
S	32	Array processing	
S	33	GR #3	

BLOCK V - Distributed processing

S 34 Distributed systems

S 35 Configurations and considerations

S 36 Distributed systems applications

S 37 Networking

D 38 "

D 39 "

D 40 Laboratory

D 41 LAB "

S 42 Fith generation project

S D FINAL

4

EE 488 References
Computer Engineering

Booth, G. M., The Distributed System Environment, McGraw Hill, New York, 1981. (QA76.9.D5B66)

Hockney, R. W., and Jesshope, C. R., Parallel Computers, Adam Hilger Ltd, Bristol, England, 1981. (QA76.6.H6 1981)

Ibbett, R. N., The Architecture of High Performance Computers, Springer-Verlag, New York, 1982. (QA76.9.A73I26 1982)

Lytel, A., Fundamentals of Computer Math, HW Sams Co, New York, 1964 (QA76.5.L99)

Parker, Y., Multi-microprocessor Systems, Academic Press, London, 1983. (QA76.5.P273 1983)

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COMPUTER ENGINEERING

Iliffe, J. K., Advanced Computer Design, Prentice-Hall, 1982.

Siewwiorek, D., Bell C. G., and Newell A., Computer Structures: Principles and Examples, McGraw-Hill, 1982.

APPENDIX J

PROGRAM CRITERIA CHECKLIST
PROGRAMS IN COMPUTER SCIENCE AND ENGINEERING

CURRICULUM

1. Does the program provide an in-depth study of one of more of the major areas of computer science and engineering? ___Yes ___ No

2. Are studies or courses in the following mathematical topics included

   a. Differential and integral Calculus? ___Yes ___No

   b. Discrete mathematics? ___Yes ___No

   c. Probability and statistics? ___Yes ___No

   d. What additional mathematics is included? _____

3. Does the program provide a balanced view of hardware and software, of application tradeoffs, and of the basic modeling techniques used to represent the computing process? ___Yes ___No

4. What engineering science course(s) outside the major areas of computer science and engineering is included? _____

5. Consider the laboratory program.

   a. Is there a variety of problem-solving and design experiences? ___Yes ___No

   b. Are the following included

      1. Hardware implementation? ___Yes ___No
      2. Programming at assembly language level? ___Yes ___No
      3. Development of documentation skills? ___Yes ___No

6. Consider the use of computers.

   a. What programming languages are used? _____
   b. What is the principal modern language used? _____
   c. What major operating systems are studied? _____
   d. Are good software documentation skills developed? ___Yes ___No

PROGRAM CRITERIA CHECKLIST
ELECTRICAL AND ELECTRONICS ENGINEERING

CURRICULUM

1. Does the curriculum provide breadth for all students? ___Yes ___No

   What parts of electrical and electronics engineering are studied by all students? _____

2. Does the curriculum provide depth in requiring study of one or more areas of electrical and electronics engineering at an advanced level? ___Yes ___No

   How is this achieved? _____

3. Consider mathematics:

   a. Does the program include calculus and differential equations? ___Yes ___No

   b. Which advanced topics are included?

      1. Leaner algebra and matrices _____
      2. Probability and statistics _____
      3. Partial differential equations _____
      4. Numerical analysis _____
      5. Advanced calculus _____
      6. Complex variables _____
      7. Discrete mathematics _____
      8. Other (state) _____

   c. Is the advanced mathematics used in advanced engineering courses? ___Yes ___No

4. What engineering science course(s) outside the major area of electrical and electronics engineering is included? _____

5. Are the advanced design classes taught in a manner that permits individual attention to each student? ___Yes ___No

6. Does the laboratory program combine elements of theory and practice and develop engineering graduates who are proficient in experimental work? ___Yes ___No

7. Consider computer use:

   a. What high level languages are used? _____
   b. What software packages are used? _____
   c. Are programs carefully documented by students? ___Yes ___No
   d. Is effective use made of systems software? ___Yes ___No

APPENDIX K

SELECTED GRADUATE COLLEGES WITH PROGRAMS
IN
COMPUTER ENGINEERING

Arizona State University
Tempe, Arizona

Auburn University
Auburn University, Alabama

University of California
Berkeley, California

California State University
Los Angeles, California

California Istitute of Technology
Pasadena, California

Cornell University
Ithaca, New York

Georgia Institute of Technology
Atlanta, Georgia

Louisiana State University
Baton Rouge, Louisiana

Massachusetts Institute of Technology
Cambridge, Massachusetts

Michigan State University
East Lansing, Michigan

Oklahoma State University
Stillwater, Oklahoma

Purdue University
West Lafayette, Indiana

Rensselaer Polytechnic Institute
Troy, New York

Rice University
Houston, Texas

Stanford University
Stanford, California

University of Arizona
Tucson, Arizona

University of California
Los Angeles, California

University of Colorado
Boulder, Colorado

University of Illinois
Urbana, Illinois

University of Southern California
Los Angeles, California

Yale University
New Haven, Connecticut